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5th Annual Combating Weapons of Mass Destruction Conference

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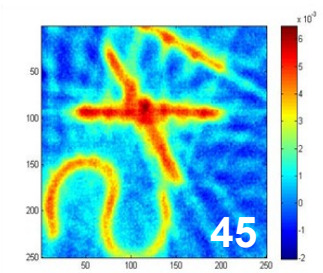

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Framing the Debate

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The challenges posed by WMD are acute, persistent, and complex. Naturally occurring health threats and the constant drumbeat from terrorism at home and abroad keeps Combating or Countering WMD (CWMD) in the forefront. CWMD with its 3 pillars and 8 mission areas crosses all six of the Army's major warfighting functions. CWMD operations and the development of versatile Army capabilities and capacity to support those operations, now and into the future require a coordinated effort throughout the Army enterprise as well as synchronization with on-going Joint, Interagency and Intenational efforts. USANCA has made it an agency priority to work with the CWMD enterprise to ensure appropriate level discussions and actions are taken to address CWMD challenges.

USANCA is shaping strategic thinking concerning CWMD. Under the OSD concept of "Big Think" that addressed the challenges and risk from various "loose-nuke" scenarios, USANCA planners developed a framework under which the Army would likely operate. Using this framework, the Army Staff looked at established force structure and potential tasks and requirements as they might impact current strategies for force deployment, force development and acquisition. These discussions were informed by and shared with the enterprise at various levels. A major outcome of these deliberations is a TRADOC led capabilities based assessment on the Army's roles, responsibilities and capabilities for land interdiction of nuclear weapons and materials. Interdiction is one of the CWMD mission areas not specifically assigned a proponent within the Army and is illustrative of the requirement to synchronize CWMD across the warfighting functions. WMD interdiction is predominately maneuver enabled by intelligence, surveillance and reconnaissance (ISR) and CBRN forces. Synchronization and collaboration are paramount to the Army's success. Furthermore, a holistic CWMD strategy that is part of the Army Campaign Plan will assist greatly in moving key strategic issues forward.

USANCA is reviewing and reinforcing a doctrinal foundation. After a top to bottom review of current doctrinal products concerning WMD, working with Geographic Combatant Commands (GCCs), U.S. Strategic Command

(USSTRATCOM), and Amry Service Component Commands (ASCCs) in development of CWMD plans, and anticipating the need for an Army CWMD strategy, USANCA identified several doctrinal disconnects and gaps. Some parts of doctrine were merely outdated such as the language in FM 100-30 (Nuclear Operations). Some parts of doctrine were missing. For example, JP 3-40, Joint Doctrine for CWMD, provides great strategic-level doctrine defining the 8 mission areas. FMs and TTPs exist and are adequate for tactical level execution of most CWMD tasks. However, the operational doctrine defining how commanders organize and C2 CWMD on the battlefield and operationalize the tenants of JP 3-40 still requires development. This lack of clear operational-level CWMD doctrine was noted and many lessons learned as a result of planning efforts with the 20th SUPCOM (CBRNE) in its JTF-Elimination role and its integration into the larger scheme of maneuver. Additionally, current doctrine does not fully address nuclear weapon employment or the nuclear weapon risk in an asymmetric environment. One of these gaps came from the cancellation of JP 3-12 (Joint Doctrine for Nuclear Operations). Recently the Joint Staff approved the reestablishment of this doctrine. USANCA is working closely with the Joint community to develop a new joint nuclear doctrine that meets the needs of the joint warfighter, now and in the future. While on the surface nuclear doctrine may appear to be the purview of USSTRATCOM, the ASCC, normally established as the Land Component Commander, is significantly impacted by nuclear weapon use. Doctrine development is a slow and methodical process and be assured that our efforts require support and input from the field.

USANCA's primary method for gaining support from the field is through our continuing planning support. USANCA has remained engaged with the supporting planning efforts at the ASCC and Field Army level. As is endemic across the force, resources are limited, and so too are the number of USANCA planners. Fortunately CWMD supporting plans are being worked on separate timelines and have not been due at the same time. This has allowed USANCA planners to move from one theater to another, focusing support. Interestingly, planning support has not been limited to CWMD, but has included engagement with theater campaign plans for partnership capacity building and other supporting annexes. The Army G-3/5/7 is looking at ways to use the Civil Military Emergency Preparedness (CMEP) program and resources as a tool to support the ASCCs. The current thinking is to establish CMEP as a global "tool" that will serve as an umbrella to pull in consequence management, health affair, security, humanitarian assistance, disaster relief, and combating WMD. Much work on that front remains ahead of us, but great strides have been made in a relatively short time. A key objective is to plan and execute Theater Security Cooperation and Building Partner Capacity that support and shape the later phases of theater CWMD plans and objectives.

The Army CWMD conference in September has been the foundation and catalysis for much of USANCA's activities. Building consensus and developing relationships through planning and coordination have been paramount as we've begun moving the enterprise forward. At the last conference we agreed to host periodic operations coordination world-wide SVTCs to continue the collaboration beyond the conference. The first session is scheduled for late January. I fully anticipate that the outcome from that will further shape the CWMD enterprise, provide insight for the Army CWMD strategy, and drive the community toward a more synchronized and focused CWMD operational stance.

5th Annual Combating Weapons of Mass Destruction Conference

MAJ Robert Cox
Nuclear and Counterproliferation Officer
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The United States Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA) conducted the 5th Annual Army Combating WMD Conference from September 14th to 16th on Ft. Belvoir, Virginia. The focus of this year's conference was the development of Phase 0 shaping tasks, specifically Security Cooperation and Building Partner Capacity.

BG Leslie C. Smith, Commanding General, 20th Support Command CBRNE provided the keynote address for the conference with a presentation that expanded upon the concept of Building Partner Capacity utilizing a real world example with the Iraqi Chemical Defense Company. BG Smith's presentation set the stage for a successful conference that included presentations that encompassed the gamut of the CWMD community of interest including the CWMD Enterprise, Civil-Military Emergency Preparedness (CMEP), National Technical Nuclear Forensics (NTNF), Counter Nuclear Threats (CNT), and the role of the Technical Escort Chemical Battalion.

Representatives from each Army Command (ACOM), every Army Service Component Command (ASCC), and several Direct Reporting Units (DRU) as well as invited service staffs attended the conference. A highlight this year was a brief from each ASCC highlighting expected enemy course of actions, CWMD exercises and engagement highlights, as well as activities specifically directed towards theater campaign plans and security cooperation.

The Army CWMD Conference provided a forum for cross-theater coordination and information sharing on a personal level, and the sharing of perspectives, insights, and lessons learned that is not normally available to members of the CWMD community thus allowing more efficient integration, implementation, and execution of CWMD policy and strategy. Numerous actionable items emerged from the conference including planned quarterly SVTC.

The next Army CWMD Conference is tentatively scheduled 13 - 15 September 2011.

BG Leslie C. Smith addresses the 5th Annual Army CWMD Conference

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The Use of Sentinel Animals for Detection of a Biological Weapons Attack

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Introduction

The scarcity of historical data regarding attacks with biological weapons means any attempt to assess the biological weapons threat is largely based upon modeling and individual interpretation. While many argue as to the real threat of biological weapons, most can at least agree that however small the threat is not zero. The military considers biological weapons a real threat and has invested in the development of detectors and protective capabilities. Currently the military has several systems to detect a biological attack. These systems are based upon three basic detection technologies; polymerase chain reaction, antibody detection or laser based detection.

Polymerase Chain Reaction (PCR) and antibody based sensors rely upon an aerosol collection device which feeds a sample into a separate detection unit. Sensors based upon PCR are more sensitive but can take several hours to detect after the sample is collected. Antibody based detection is faster (15-30 min) than PCR but much less sensitive, and subject to false positives from environmental contamination. Both of these technologies are point detectors, detecting agent at the location of the detector, which does not provide a "detect to warn" capability.

The only capability to provide "standoff" detection (detection at a distance from the sensor) uses sensors based upon lasers. These sensors rely upon absorption and florescence of laser light by biological particles to characterized clouds of organisms which can be meters to kilometers from the sensor. These sensors are the least developed to date and face significant issues with range and discrimination from background contamination.

The reality of the deployed or austere military environment places stringent requirements on sensors such as power consumption, weight, durability, interoperability, cost, consumables etc. When a military unit is in an operational environment biological detection is only one of many concerns the unit may have, and may be of low priority based upon other threats the unit may be facing and intelligence estimates of the threat environment.

For all these reasons a military unit or base may not deploy operational biological weapons sensors. A system or detection scheme that can reduce logistical or manpower constraints has a better chance of being utilized. Is it possible that animals could serve as detectors for biological agents? If so the military could deploy sentinel animals with units to provide detection of biological agents. This paper will attempt to identify and characterize candidate sentinel animals for several biological agents of concern.

Sentinel Animals

Sixty one percent of human diseases are zoonotic (diseases of animals) [1] so many biological agents will affect multiple host organisms. It may be possible to identify, and then deploy animals with military units to provide early warning to a biological weapons attack. A classic example of a sentinel animal detection system is the case of veterinarians reporting dead crows weeks prior to West Nile Virus emerging in humans.[2]

An animal detection system could be designed in several ways. A straightforward use of animals is to deploy an animal sentinel in a cage on a base where it will be exposed to the same environment as the military personnel. The animals are then checked periodically for indicators of disease. Any change in the animal's health would alert medical personnel to a deviation from the environmental baseline. Ideally the animal would be killed by the agent, making determination of health status a binary decision, not subject to interpretation or requiring physical examination such as temperature measurement.

Animals need not be in cages on the base to serve as sentinel. Local domestic or farm animals can serve as sentinels. Personnel outside the base should be aware of any diseased or dead animals which could indicate the presence of a biological agent. Wild animals can serve as sentinels as well. If a good match is present between a suspected threat agent and a local wild animal, that animal can be periodically observed or actively trapped and examined for the presence of the biological agent.

For an animal to serve as a useful sentinel it must offer some advantage over a human target. One characteristic that would define a successful animal sentinel model is the animal succumbs to the agent faster than a human, providing medical personnel an opportunity to implement medical countermeasures prior to the human exhibiting symptoms. It should be noted that these detection methods will not provide an alert to prevent infection as the base population would be exposed with the animal. However, for many biological agents providing countermeasures prior to emergence of symptoms greatly improves the chance of survival.

Another characteristic that would define a candidate sentinel animal is greater susceptibly, where a lower dose of agent would cause infection in the sentinel animal but not the human population. This can serve to

alert medical personnel of possible failed attacks, collateral exposure from a different attack, or even local endemic disease state. A sentinel animal should also demonstrate easily identifiable clinical signs as a result of infection allowing quick identification.[3] Any test that requires blood work, swabs, necropsy etc would add additional requirements on military personnel and will reduce the utility of the sentinel model system.

Animal sentinels detection may also use a vaccinated vs. unvaccinated population.[3] An example of this would be a colony of mice used as a sentinel against Tularemia. The colony would be divided into a vaccinated and unvaccinated population. Upon exposure to the threat agent the unvaccinated mice should demonstrate symptoms while the vaccinated mice remain health. This strategy provides a built in control/ confirmation capability and can help rule out other diseases that may be causing illness in the mice. A variation of this approach could utilize susceptible and resistant strains of the same species.

To have a military utility, candidate animals have several desirable characteristics. Generally, smaller animals would be better requiring less space and a reduced logistical footprint. The animal should be easy to care for, require no exotic food, bedding, environment etc. It must be able to survive transport with the military unit as it is deployed, and be able to survive exposure to the local environment.

The literature did not reveal a dedicated research effort (Department of Defense (DOD) or civilian) to methodically test animals for the capability to serve as sentinels against threat agents. There are some older descriptions of affects on animals produced by researchers from the United States (U.S.) Army Medical Research Institute of Infectious Diseases, (USAMRIID), most likely a result of the U.S. offensive biological weapons program. These sources are extremely useful as the researchers often exposed animals to aerosolized agents, as would be expected from an actual attack. As the United States has abandoned its biological weapons program, most recent data has been generated for other purposes with varying degrees of applicability to biological weapons.

Current research predominantly falls into two categories; disease affects on animals as described in the veterinary literature, or researchers seeking to identify animal models for drug or vaccine development. However, caution must be taken as many researchers utilize specific strains of the causative agents or special strains of the animal model. These data points may provide useful to identify potential sentinel animal candidates, but sentinel animals would to be tested specifically for exposure route and causative agent purpose prior to use in the field.

Literature searches revealed only two attempts to develop a systematic description biological weapons affects on animals; “Animals as Early Detectors of Bioevents” by Diane Gubernot and “Animals as Sentinels of Bioterrorism Agents” by Peter Rabinowitz. Peter Rabinowitz has also produced the “Canary Database” (http://canarydatabase.org) which attempts to cross reference diseases and chemicals of interest with animals that have some capability to serve as sentinels. Within these efforts, as would be expected, greater information is available on higher threat agents like Anthrax, with less information available on agents such as Glanders . Event within these databases, the available references are spotty at best.

Anthrax

Anthrax is caused by the bacteria *Bacillus anthracis*. A spore forming bacteria that primarily infects grazing animals. As a biological weapon the spores are extremely effective if dispersed as an aerosol allowing infection via the respiratory tract, causing pulmonary Anthrax. For humans the infectious dose is relatively high, estimated in the thousands of spores. Inhalation Anthrax is deadly with a mortality rate of 45% treated and 90-100% untreated. [4] The literature on the incubation period for inhalation Anthrax in humans is variable, Iowa State’s Anthrax site states two days to several weeks [6] while USAMRIID‘s Medical Management of Biological Casualties Handbook, (known as “the blue book”) states 1-6 days. [5]

Mice, guinea pigs and rabbits are routinely used in the laboratory as models to study Anthrax. These studies provide information on lethal doses (LD) for the animals, and also highlight the effect of animal strains and infectious dose on survival. In mice lethal doses ranged from 1,900 spores to 34,000 spores depending upon the strain of mouse used, while time to death was approx 2-3 days after receiving a dose of 100 LD_{50}. [6] Studies using a lower infectious dose of 5 LD_{50} saw 20% survival in mice with a time to death of 2-8 days. [7] Rabbits showed similar results, animals exposed to 100 lethal doses (1 lethal does is 1 $x10^5$ spores) died in 2 -4 days. [8] In guinea pigs the lethal dose is reported as 7.9 X 10^4 spores. Exposure of 216 LD_{50} resulted in death an average time to death of 2.3 days.[45]

From a military operational standpoint any of these animals could be candidate sentinels based upon size, logistical requirements and relative ease of care. Mice would probably be preferred based upon size. If one assumes the human LD_{50} is 2,000-5,000 spores, all of these animals have similar susceptibility. The advantage of these animals is that, with higher doses, they start to die after about two days. This is when human symptoms would start appearing, so sentinel death may provide a small opportunity to initiate treatment prior to the majority of human cases demonstrating symptoms, or at a minimum could serve to corroborate initial symptoms being reported by medical personnel.

Studies from the Sverdlovsk Anthrax release indicate that two animal species, sheep and cows may have greater susceptibility to Anthrax when compared to humans. Analysis of the release indicated that in several towns along the predicted axis of deposition sheep and cows died of Anthrax while no humans in the vil-

lages became sick. Computer modeling of the release predict these animals received a dose of Anthrax one order of magnitude less than the areas reporting human outbreaks. [9] Analysis of Anthrax outbreaks in Texas indicated that horses and mules had greater incidence of Anthrax when compared to cows, possibly due to different grazing habits which expose horses to more soil than cows. [10]

As militarily significant animals, cows, sheep and horses would not be useful sentinel animals. However, as ruminant animals are a natural host of Anthrax, and are exposed to any ground contamination through grazing, they may have some utility. In the case of a failed or remote Anthrax attack local ruminant animals may be affected by an attack that did not impact military personnel. Military doctrine already teaches soldiers to be aware of wildlife deaths as an indicator of hazardous environments (chemical or biological). Likewise monitoring local pastures may be a possible indicator of a low level exposure. Any military unit located near farmland should be especially aware of the health status of these animals

Military working dog in Afghanistan. Photo Credit: DOD

One animal that the military specifically deploys with are military working dogs. However, canines are extremely resistant to Anthrax and would not serve as a sentinel species. Researchers from Ft. Detrick subjected pigs and dogs to Anthrax aerosols. Both animals developed pulmonary lesions, and researchers were able to recover viable Anthrax from the animals. However, they did not develop systemic Anthrax, or exhibit high mortality rates.[11]

Plague

Plague is caused by the bacteria *Yersinia pestis*. As a disease, Plague can present in humans in three forms; bubonic, septicemic and pneumonic. The most common natural route of infection for humans is through the bite of an infected flea. As a biological weapon, *Y. pestis* would most likely be delivered via an aerosol, resulting primarily in the pneumonic manifestation. USAMRIID's stated infectious dose is 500-1,500 organisms. [5] Most human symptoms would appear 2-4 days post attack with a range of 1-6 days. Case mortality rate without antibiotics approaches 100%. [12]

Over 200 mammalian species can be infected with Plague. [13] Animals of interest include; coyotes, skunks and raccoons which can seroconvert without symptoms. Plague is fatal to chipmunks, wood rats, ground squirrels, deer mice and vols. The animal with the highest mortality rate is prairie dogs where it approaches 100%. [14] The high mortality rate and relative ease of maintenance in captivity would make prairie dogs a candidate sentinel animal. However incubation time between prairie dogs and humans is similar.[15] At best prairie dogs could serve to confirm an attack but would do little to assist with preemptive medical intervention.

Cats are relatively susceptible to Plague. Infection of cats via infected mice producing illness in 81% of cats. [16] Cats may provide a small window for early medical intervention. There is evidence indicates that for inhalation acquired *Yersinia pestis* the incubation period for cats is 1-2 days while human incubation can take from 1-6 days. [17] While the incubation times overlap, the average onset time for cat infections appears earlier than in humans.

As with Anthrax, dogs appear relatively resistant to Plague with fever reported from infection but no mortality. [18] It is good that military working dog assets have a natural resistance to Plague, but removes readily available and deployed animal from contention as a sentinel species. The ability of dogs to harbor Plague without severe symptoms [19] may be of concern as they could serve as a reservoir for human spread

Tularemia

Tularemia is a bacterial disease

caused by *Francisella tularensis*. Two sub species exist with the type A strain much more infectious and deadlier than the B strain. [20] It is a naturally occurring disease in rabbits, hares and some ticks. [21] As a biological weapon, deployed as an aerosol, Pulmonary Tularemia would have a mortality rate of approx 50% untreated, but with antibiotics that would be reduced to approximately 2%. [20] In humans (and most animals) Tularemia has an extremely low infectious dose, on the order of ten organisms. [5] For this reason there is little expectation that a sentinel animal species could be selected based upon greater susceptibility.

In addition to its low infectious dose Tularemia affects humans and many animals rapidly. In humans the disease latency period is approximately 3-5 days, [21] but can range from 1-14 days. [20] Many standard laboratory animals (mice, rabbits and guinea pigs) are susceptible to Tularemia and are killed too "rapidly" to be suitable laboratory models. [22] Mice challenged with an aerosol delivery die within 4-7 days of exposure [23] which is similar to human parameters. Infected marmosets also follow a disease course similar to humans. With a dose of one LD_{50} (less than 10 organisms), temperature rise was observed approximately 2.5 days after infection followed by death 12-18 hours later. [24]

Researchers looking for vaccine modes using mice report that numerous species of mice can withstand up t a 10^5 injection of Tularemia post vaccination, but all species were still susceptible to aerosol challenge (vaccinated or unvaccinated) with time to death ranging from 5-21 days depending upon species. [23] The wide range in time to death between species highlights an additional challenge for selecting sentinel animals. Most laboratory work is done with specific species and strains of animals. Any data regarding mortality or susceptibility may not be universal for all. Any detection scheme must ensure that the correct strain is picked for deployment.

It might be possible to use animals as sentinels for Tularemia utilizing a susceptible species and non-susceptible species scheme. A laboratory animal that demonstrates much greater resistance to Tularemia is Sprague-Dawley rats (dosed at 10^5 organisms).[22] Death of a susceptible mouse strain, accompanied by survival of the Sprague-Dawley rats could indicate a Tularemia attack.

Other animals that show resistance to Tularemia include pigs, where experimental does of 10^6 organisms were required to induce mild symptoms appeared. [25] Likewise, dogs and chickens demonstrate much greater resistance to Tularemia. [26] This is good because military working dogs will have natural immunity while performing their duties, but unfortunate in that if they were susceptible they would serve as good, mobile sensors.

Encephalitis Viruses

Multiple Encephalitis viruses exist in nature and have the potential to be weaponized. Most of these viruses are maintained in animal reservoirs and are transferred to humans through infected mosquitoes. This is one area where public health programs have initiated sentinel animal programs. The USAMRIID blue book states that in natural outbreaks equine mortality "always" precedes disease in humans. [5] In outbreaks where human deaths are reported the ratio of equine deaths to humans runs approximately 100:1. [27]

A relatively robust sentinel system has been established domestically for many Encephalitis viruses using birds as sentinel animals. Reports of dead crows preceding West Nile Virus in humans is a classic example of sentinel animals. [2] Chickens are used as sentinels for St. Louis Encephalitis in Florida, where detection is based upon weekly blood draws or PCR on nasal swabs. [28]

Michigan's Encephalitis surveillance plan depends upon trapping and testing mosquitoes for the West Nile Virus and Eastern Equine Encephalitis viruses. Reporting and testing of dead birds has been discontinued as evidence indicated wild birds had become relatively resistant to lethal viral infections. [29]

While these plans are successful in gauging the natural background of Encephalitis viruses and predicting possible outbreaks, they would be of limited utility against a biological attack. The testing schemes rely upon periodic sampling of animals via blood draw or swabs to check for the presence of virus. These types of tests would require additional time and equipment that would not be conducive for a military unit.

Venezuelan Equine Encephalitis (VEE)

VEE was considered for use as a biological weapon by the United States. It has an extremely low infectious dose (tens of virons), with an incubation period of 2-6 days. [5] Additionally while the disease is highly infectious it is relatively benign in that only 1% of infected individuals will develop Encephalitis, with a subsequent 10% of those individuals dying.[30] From a military standpoint this agent has been investigated as a more "humane" biological weapon, designed to incapacitate prior to an attack, without mass mortality.

Hamsters were also used in an attempt to survey for VEE in Florida. In the study 35 hamsters were exposed for approx 16 days. Sixteen of the hamsters died, but VEE was only recovered from one animal. Combined results from other sites recovered 6 VEE positive hamsters from 60 sentinel animals. Of the 6 two died and 4 were described as "sick" but survived for 2 months.[31] While these animals/collection techniques would not serve tactical sentinels they could work for medical or environmental personnel conducting a site survey of a base to help determine the local disease load.

Glanders

The causative agent of Glanders is *Burkholderia mallei.* Glanders is a relatively common zoonotic disease, but relatively rare in humans. Data on infectious dose, especially aerosol delivery, is not well documented but the disease is categorized as "highly infectious" with most laboratory infec-

tious acquired via routine handling vs. accidental inoculation. [32] USAMRIID does not have a specific infectious dose simply stating "low" for infectious dose.[5] When deployed in an aerosol attack the incubation period is expected to be 10-14 days. Untreated pulmonary infections usually proceed to the septicemic form of the disease. Death often occurs 1-2 days after septicemia develops.[33]

Glanders is primarily a disease of horses, mules and donkeys. Cattle, pigs, mice and birds are highly resistant. Hamsters, guinea pigs and cats are also susceptible.[46] Death in mules usually occurs in 3-4 weeks.[5] Cats infected with Glanders develop yellow nasal discharge which becomes bloody, death usually occurs in 1-2 weeks.[33]

Research from (then) Camp Detrick provides an excellent summary of relative susceptibility for several species to Glanders and Melioidosis (discussed in next section). The study showed that Hamsters and ferrets were the most susceptible. Hamsters had a Minimum Lethal Dose (MLD) of 20 organisms and death occurred in approx 3 days, the MLD for ferrets was <90 organisms with death in 8-15 days. Guinea pigs were also susceptible with death in 1 day to 3 weeks depending upon infectious dose (23-500,000). Rabbits were resistant, surviving an IV dose of 300 million organisms; as were white rats surviving infectious doses of 1 million. Mice were only slightly susceptible requiring a dose of 2.5 – 30 million organisms to kill, while infections of less than 450,000 organisms causing no death. For monkeys, doses of 1.5 million organisms caused abscesses, increased temperature and weigh loss.[34]

Based upon the Fort Detrick data hamsters and guinea pigs could serve as sentinel animals for Glanders. They are susceptible to low infectious doses, respond to the infection quickly, and the disease is lethal for them. They are small, easy to care for and would have a relatively small logistics footprint. However, because of the relatively little amount of human data, it is not possible to compare sensitivity data. Also mortality rates are similar to what has been observed in humans. They might work better for low level exposures, but it would not be possible to know for sure how the animals or humans would respond to a massive dose associated with a near field biological release.

Melioidosis

Melioidosis is the disease caused by an infection with *Burholderia pseudomallei*. This bacterium is very similar to *B. mallie*, exhibiting over 70% DNA-DNA homology.[35] In the literature and medical references Melioidosis and Glanders are often discussed together. The USAMRIID blue book gives guidance that the disease and symptom of Melioidosis is expected to be similar to Glanders in the case of a large scale aerosol inoculation expected in a biological attack. Infectious dose for humans via aerosol is categorized as "low," with an incubation period of 1-21 days and death in 2-3 days after development of septicemia.[5]

In addition to aerosol research on Glanders (above), researchers from Camp Detrick also examined Melioidosis . The study showed that hamsters had a MLD of 60 organism (mortality in 80 hours); and ferrets had a MLD of <72 organisms (8-15 days to mortality). These were the most susceptible animals.[34] Hamsters and ferrets are relatively easy to care for and could be candidates as sentinel animals for Melioidosis , however the low incubation period in humans of possibly one day (but possibly up to years)[5] would not assure every attack would be detected by animals prior to initial human casualties.

Other animals can be ruled out as possible sentinels. Rabbits and rats are resistant. Rabbits survived an IV dose of 300 million organisms and rats showed mortality only after inoculations of 1 billion organisms. Monkey response was similar to Glanders, a 1.5 million organism dose was required to produce abscesses, elevated temperature and weigh loss. Results on guinea pigs were inconstant with mortality and survivors observed for every infectious dose over a range of 26 – 2.6 x 10^5 organisms.[34]

Other literature lists the disease as common among sheep and goats, rare in cows, and resistant in pigs and birds. Camels, grey seals and dolphins, fish, monkey and even crocodiles have been documented hosts for the bacteria.[35]

Research into non-mammalian models has identified the ability of *B. pseudomallei* to kill nematodes. Nematodes were allowed to feed on a bacterial lawn and monitored for affects. In this study death occurred (LT_{50}) occurred 10-15 hours post feeding.[36] Nematodes would make a good sentinel organism as they are cheap and easy to maintain. However, this study did not measure a lethal dose, as a bacterial "lawn" was used to infect the nematodes through feeding. Additional study would have to be conducted to establish a mechanism for capturing environmental samples and exposing it to the nematodes.

Q Fever

The causative agent of Q fever is *Coxiella burnetii*. USAMRIID's blue book gives the following characteristics of Q fever. The infectious dose is extremely low, 1-10 organisms. Human incubation of inhaled *Coxiell*a is 7-21 days, varying with infectious dose, while naturally occurring infections can range up to 45 days. The disease has a low lethality rate, among patients exhibiting symptoms only 5% will require hospitalization. For those developing pneumonia lethality is less than 3%. However the disease is extremely persistent lasting from 5-57 days untreated, with approx 5% developing a chronic infection lasting for years.[5]

As with humans, symptoms in animals are relatively mild. In animals the incubation period is 1-3 weeks, with the predominant symptom being an increase in abortions.[15] The similarity in incubating period and the low occurrence of overt disease symptoms makes animal sentential detection unlikely.

In rural areas the disease is rela-

tively common in the environment with 10% of humans and 50% of sheep having antibodies against *Coxiella*.[37] Environmental surveys in California detected seroconversion in Dogs (48%), Horse (26%), cat (9%) and cattle (32%). The authors suggest that dogs may be a sentinel species capable of reflecting the environmental prevalence of *Coxiella*.[38] However the ability of significant numbers of these animals to survive asymptomaticaly, and the need to test for antibody presence would not make them candidates for field deployable detection.

Two animals that logistically are good sentinel animals are mice and guinea pigs. However their ability to survive large infectious does (when compared to 1-10 organisms for humans) would prevent them from serving as sentinel animals. In mice aerosol challenge studies using 10^2, 10^4, and 10^6 infectious doses did not cause mortality among CB-17 (immune competent) mice whereas the LD_{50} for immune compromised mice was 10^2 organisms.[39] Immune competent mice demonstrated ruffled fur fro 4-13 days after an 10^6 infection, but no other symptoms were observed. Some studies have suggested that the LD_{50} for mice may be as high as 10^8 organisms.[40]

Guinea pigs given the same aerosol challenge as the mice exhibited death in 7-9 days for some strains, while in other strains no fever or clinical signs of disease were observed.[39] Additional guinea pig studies show an LD_{50} of approx 10^6 organisms resulting in death in 7-10 days post infection. Illness severity and mortality was directly correlated with dose. Lower doses caused fever and weigh loss but no mortality. [40]

Hemorrhagic Fevers

"Hemorrhagic fevers" is a category that includes several viral infections that have bleeding as a symptom. There are several viruses of interest in this category including Ebola and Marburg. Infectious dose can be as low as 1-10 particles,[41] and the prevalence of natural infection scan range from a handful of infections per year (Ebola, Marburg) to hundreds of thousands per year (Lassa) Incubation can range but can be as low as 2 days. Specific incubation periods are; Ebola 2-21 days, Marburg 2-14 days, Lassa 5-16 days, Rift Valley fever 2-6days. Mortality for some agents is low as 5% for yellow fever, and can be as high as 90+% for Ebola and Marburg.[41]

These viruses are relatively rare, often occurring in lesser developed countries. In many cases the natural reservoir and/or vector(s) is still unknown. For diseases such as Ebola there is little data and few good animal models have been developed to study the viruses. Most current animal research is based upon attempts to identify animal strains to serve as models, or efforts to modify the viruses to allow infection of common laboratory animals. Therefore there is little evidence to identify even candidate sentinel animals.

To create an acceptable mouse model for Marburg, the virus was passed through several rounds of immune compromised mice to reduce death from 50-70 days to 7-10 days.[42] This process in essence "evolves" the virus into a form that will infect the model animal, but the resulting laboratory virus strain is no longer identical to the wild type strain.

Small animals have been examined in attempts to understand natural reservoirs of Congo Crimean Hemorrhagic fever. Exposure showed low level viral titers and antibody production was observed in scrub hares, cape ground squirrels, red veld rats, white tailed rats, bush veld gerbils, striped mice, and guinea pits. South African hedgehogs did not develop viremia. Of importance when looking for sentinels, none of the animals were observed sick during the experiment.[43]

Non human primates are known to be susceptible to Ebola, with some human outbreaks thought to be a result of contact with infected primates. Environment sampling of chimpanzee, ape and duiker carcasses for the presence of Ebola was able to predict human outbreaks with several weeks warning.[44] While primates serve as laboratory models for Ebola they would be extremely difficult to care for in a field environment. In an area with a natural primate population sudden die offs should serve to alert medical officers.

Conclusions

The literature reveals many challenges in establishing sentinel animal models to detect biological weapons. There are very few animals that will provide significant reaction to a biological attack prior to initial human casualties. This is partly due to the fact that for many agents the infectious dose for humans is in the 10's to 100's of organisms giving an extremely small window where an animal could be affected but not a human. The two agents with higher LD_{50} values (Plague and Anthrax) are possible exceptions, where guinea pigs and ruminant animals show to be more susceptible.

Selecting sentinel animals based upon incubation time is also a challenge. For all the agents examined the incubation time between model animal and humans overlapped. The best candidates in this category are; cats, which may provide a 1-2 day warning for Plague, and hamsters / guinea pigs which may provide a 1-2 day warning for Glanders. The advantage sentinel animals may offer is that they are often exhibiting mortality at about the same time human symptoms start to appear. Depending upon the event this may or may not provide any advanced warning, but animal mortality combined with any unusual symptoms at the clinic should put medical personnel on alert as to an extraordinary event.

The literature also highlighted the species/strain affect on infection and mortality. For the same agent animal sensitivity can range at least one order of magnitude based upon which strain of animal is selected. Similarly most research is done using specific strains of the biological agents. Again different strains cause different responses in animals, so extrapolation from one strain of bacteria to all possible biological agents may not be valid.

Another challenge is finding unique symptoms for each disease. An example listed in "Animals as Early Detectors of Bioevents"[15] summarizes some possible symptoms and their causes. For canines sudden death could be; Anthrax, botulism, toxins, Plague or Tularemia. Likewise acute respiratory disease could be Anthrax, Plague, Tularemia, Melioidosis or Naipah. It is therefore unlikely that a single animal/threat agent system could be worked out. Therefore the most likely and realistic use of animals would be to key medical or environmental personnel to conduct reconnaissance of the area and hopefully provide enough lead time to initiate effective counter measures.

A final challenge is extrapolating dose and incubation values from the different types of data that have been generated. As the majority of the biological agents are lethal, values for human lethal dose and incubation time cannot be determined through rigorous laboratory experiments. Most data is derived from laboratory accidents or naturally acquired disease and may not represent what would occur in a deliberate release via aerosol.

Based upon the available data, it is difficult to envision a dedicated program to utilize animals as sensors for biological weapons. In some instances animals may provide 1-2 days advanced warning of an incident, which would allow for medical care prior to emergence of human symptoms. Most animals would show affects at the same time they appeared in humans. However, this is not to say that animals are useless. It is likely that in an attack at least one local domestic or wild animal would be affected. Astute military medical personnel should be aware of this potential and incorporate animals as one of the many data streams used for situational awareness.

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Government Medical Countermeasures and Public Acceptance, a Mismatch?

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The federal government, through the departments of Homeland Security and the Centers for Disease Control, has taken steps to mitigate the effects of a biological attack against the United States (U.S.). With minimal ability to detect a biological attack in time to provide enough advanced warning to avoid the hazard, medial countermeasures are the prime modes of defense against a biological attack. One of the key components of the government plan is the Strategic National Stockpile (SNS). The stockpile is composed of medical equipment, vaccines and antibiotics and is designed for rapid deployment in the event of an attack.

The effectiveness of the government response is dependent upon several key variables. The attack must be detected in a timely manner, the decision to distribute the Strategic National Stockpile must be made, the stockpile must be delivered to the attack site, the countermeasures must be distributed to the population in a timely manner and the population must correctly utilize the medical countermeasures. The government has the least amount of control over this last step, yet countermeasures are worthless if not used correctly. This raises an important question concerning attack response; will the public take advantage of the countermeasures provided by the government?

There are many opinions on what effect a biological attack would have on a city. Casualty estimates range from hundreds to hundreds of thousands. However, there is no question that the timeliness of initiating medical countermeasures has a direct impact on the number of casualties. Time is critical because with most biological agents there is a point where medical countermeasures cease to be effective in preventing casualties. It is usually at the point where an individual starts to demonstrate symptoms of the agent when countermeasures cease to be effective.

Fortunately there is relatively little historical data reading mass casualty attacks utilizing biological agents. Therefore, predicting public acceptance of countermeasures must be extrapolated from several different sources of data. The most applicable data source is the "Amerithrax" attacks, where the rate of antibiotic use by U.S. Postal personnel has been well documented. In addition to the Amerithrax case studies, examination of Anthrax vaccine uptake by U.S. military personnel, studies that examine the general attitude of Americans towards government public health efforts, and the results of war games can provide insight on how the public will respond to countermeasures.

The Effects of Biological Weapons - Anthrax

While the issues addressed in this paper would apply to any biological agent, Anthrax will be predominantly utilized as the model attack organism. There are several reasons for this. The predominant reason is that the 2001 biological weapons attack utilized Anthrax, which provided a large amount of data utilized in this article. Additionally, the ability of Anthrax spores to resist antibiotics and remain viable for an extended period of time represents a worst case scenario for officials trying to mount an effective countermeasures campaign (assuming the weapon used has effective countermeasures).

Even with the current detection capabilities available in some US cities it is still extremely unlikely that a biological attack will be detected in real time. The most likely scenario for an attack against a city equipped with Biowatch sensors would be detection of the attack 12-24 hours after the attack occurred. At this point most people who will be affected by the attack have already been exposed. In the event of a positive sensor reading, the government would then need to confirm the attack, make a decision how to respond, and then issue the order to utilize the national stockpile. It is realistic to assume that antibiotics would most likely arrive 24-48 hours after the attack occurred.

For an agent such as Anthrax, affects in humans will be observed in 1-6 days after attack. Symptoms start off as "flu like" which can last 2-5 days. The patient may then feel better for a day or so but will develop severe respiratory symptoms, with death occurring 24-36 hours later. Death is caused by severe respiratory symptoms and septicemic shock. Patients administered antibiotics post infection, but prior to the emergence of symptoms have a high survival rate. The traditional medical belief is that if antibiotics are initiated after the appearance of symptoms the case fatality rate is >85%. Information gained from the mail attacks showed the fatality rate can be lowered to 45% but requires intensive care facilities and aggressive medical treatment.[1]

Affects of Time and Antibiotics

It is this in small time window between exposure and symptoms that the government must provide antibiotics if they are to effectively reduce casualties without overwhelming medical facilities. For a weapon such as Anthrax this timeline is essential,

as the after the first 24- 48 hours antibiotics have a reduced effectiveness of up to 80%.[2] As cases of human inhalation Anthrax are relatively rare, most information on antibiotic efficiency is based upon animal studies. Research has shown that in rabbits, delay of antibody treatment by 24 and 48 hours post exposure reduced survival to 80% and 60%, respectively.[3] Similar data was obtained in mice where treatment initiated 6, 24 and 48 hours post exposure had respective survival rates of 90%, 65% and 10%.[4]

A characteristic of Anthrax spores which complicates medical treatment is their ability to remain infectious in the lung for extended periods of time, where they can germinate asynchronously and often cause infection long after exposure.[3] As long as viable spores remain in the lungs it is possible to develop an Anthrax infection. Compounding this issue is the fact that current antibiotics do not kill the spores, but kill the vegetative bacterial that emerge from the spores. Therefore to ensure that antibiotics are present in the patient's body when the spores germinate antibiotics must be taken for extremely long periods. Sixty to 100 days is recommended for Anthrax.[5]

Modeling efforts demonstrate the pronounced affects time and access can have on the number of casualties from a biological attack. A simulation run by Wein attempted to include factors such as adherence to prophylaxis and time to distribute antibiotics. Based upon their calculations the impact of prophylactic adherence is large, the death toll is 50% higher if prophylaxis adherence is reduced to from 90 to 80 percent.[6] They also found that the death count is sensitive to the number of antibiotic distributors per capita, and the number of deaths can be nearly halved by eliminating queuing, which can be achieved by a 7.5-fold increase in the distribution capacity or by pre-attack distribution.[6] Another model predicts two important factors in preventing mortality. In a mass attack, the rate of antibiotic delivery capability dominates mortality calculations. Once the delivery rate is greater than 420,000 persons per day antibiotic adherence becomes the dominant variable.[7]

National Response Plans – The Strategic Stockpile

The government response plans are dependent upon rapid delivery, dispersal and use of antibiotics or vaccines. The Centers for Disease Control (CDC) Cities Readiness Initiative assumes a twelve hour delivery of antibiotics from the Strategic National Stockpile, followed by a local distribution of the pharmaceuticals.[8] In many ways national response policy to utilize the stockpile is still in development. Most recently Executive Order 13527 was signed on 30 Dec 2009 which gave the U.S. Postal service 180 days to develop plans to distribute antibiotics from the stockpile.[9] While the resulting plans are yet to be published, concerns have been raised over security, postal worker abandonment and even how to treat P.O. boxes.

While most planning document and simulations appear to focus on delivery timelines and effective distribution, it is unclear if any assumptions are made regarding uptake of countermeasures. For example, areas of concern identified in "Top Off" exercises include complication with distribution, synchronization between state and federal authorities and quarantine but issues of public acceptance of countermeasures were not listed.[10]

Likewise the issues of communication and education regarding the treat and countermeasures do not seem to get significant emphasis. Executive Order 13527 focuses on distribution but does not address education or communication.[9] In planning guidance for local communities developed by the Department of Homeland Security there is information on arrival of casualties, distribution of drugs, flow plans, staffing, facility set up, and paperwork etc. The need for effective communication is addressed but not stressed relative to importance and uptake of antibiotics.[11]

Observations from Postal Workers

While the need for timely and correct use of countermeasures has been documented, there is evidence that a significant portion of the population may not use available countermeasures. In 2001 Anthrax spores were sent through the U.S. Mail. In this attack several distinct populations; postal workers, media, and Senate workers were exposed to Anthrax spores either through letters received or while working in the postal facilities that processed the letters. A cohort of approximately 10,000 individuals was recommended to follow a sixty day course of antibiotics. The largest population was the Brentwood mail facility (2,743) and the smallest was the Hart Senate Building (600).[12] These populations have been the subject of intense study and offer significant insight into the behavior of individuals facing a biological attack.

Medical records and subsequent research using focus groups and interviews provide data regarding the use and effectiveness of antibiotics and help identify factors influencing uptake of countermeasures. The data shows that while antibiotic use was relatively high, there were significant numbers of individuals who; did not accept antibiotics, accepted but did not start antibiotics, or started antibiotics but discontinued use prior to completing the full course of treatment. A gross analysis of the 10,000 individuals offered antibiotics showed 97% received an initial supply, 83% received a full 60 day dose, 10% took no prophylaxis, and only 44% took the full course of antibiotics.[12]

Deeper analysis of the data reveals several variables that influenced acceptance of medical countermeasures. Unsurprisingly the more an individual believes themselves to be at risk of exposure, the greater their likelihood to initiate and continue antibiotic treatment. Stein reports "People who were informed that their swab was positive concluded that they were at highest risk. In contrast, many participants mistakenly interpreted negative swab results as a signal that they were at low risk"[13] Shepard reported "Strong association between risk perception and completion of antibiotics."[12]

Specific evidence linking risk perception to antibiotic use is documented in several studies. In the Connecticut postal facility overall refusal rate for antibiotics (32 of 100 surveyed) was higher than the average number of 10% cited by Shepard. The Connecticut facility was identified and tested 30-40 days after likely exposure, making detection unlikely. As expected all 485 nasal swabs were negative for Anthrax. In that facility of those refusing antibiotic nineteen (59%) stated that they did not feel they were at personal risk for Anthrax. and (47%) cited negative nasal swabs of workers[13] Additionally of the 68 postal workers that did start antibiotics twenty one discontinued, over half citing lack of personal risk as the reason.[13] Shepard's study looked multiple populations and found 43% stopped antibiotics prior to 60 days, with 25% of those individuals citing personal risk as the determining factor. [12]

Similar to lacking fear of exposure, the sentiment "since I do not feel sick, I do not need to take medicine" was also identified as a factor. [13,14] This sentiment is dangerous for at least two reasons. As already discussed the effective treatment of Anthrax is highly time dependant and Anthrax is extremely fatal once symptoms develop. Secondly, the possible long term germination of Anthrax spores makes it possible for infections to develop many weeks after exposure. This attitude affected both decisions to stop antibiotics prematurely[13] or not to take antibiotics in the first place. [14]

Personal risk assessment also appeared to influence personal decisions on what type of countermeasure to use. In addition to antibiotics, the Anthrax vaccine was also offered as a supplement to antibiotic treatment. The use of the vaccine post exposure was experimental and was offered voluntarily. In the Senate population 38% of the high risk individuals chose to receive the vaccine. However the same offer was only accepted by only two percent of the Brentwood postal workers. [15] The likely factors influencing of the two different response rates is communication and trust in public health which will be discussed in greater depth later.

Another reason influencing antibiotic compliance commonly cited in the literature is adverse reactions to the antibiotics. The antibiotic initially administered to most exposed individuals was Ciprofloxin. As with any drug there are side effects associated with antibiotics which include can range from intestinal problems, itching, swelling and even difficulty breathing.[16] For individuals expected to take at least sixty days of antibiotic treatment it is not unrealistic to expect side affects to have a significant role in compliance. In fact issues associated with adverse reactions were observed in all of the locations studied.

Studies of Brentwood employees report that approximately 20% reduced their dosage (without consulting a physician) because of side effects.[17] Surveys of those exposed in Florida showed 19% reporting adverse reactions and over 6% stopping antibiotics because of side effects. [16] The Brentwood study also identified a possible compounding factor in that normal stress response (fatigue, crying, headaches etc) were mistaken for antibiotic side effects, which adversely impacted compliance. [17] Other facilities all reported about the same number of individuals stopping antibiotics because of side affect concerns. Surveys of the six sites receiving antibiotics showed 43% of those stopping antibiotics cited adverse reactions. [12] Surveys of the Connecticut facility also found that 43% of individuals prematurely stopping antibiotic treatment cited side effects. [14]

The surveys also identified additional smaller but measurable reasons for not taking antibiotics. Shepard reported that seven percent of individuals ceasing antibiotic treatment cited long term fear of antibiotics. [12] At the Connecticut facility 13% of workers cited concern about antibiotics/side effects as reason not to even start treatment. Also captured at the Connecticut facility was the sentiment "many postal workers reported obtaining the antibiotics to 'have on hand' in the event 'I start to feel sick." [12]

Communication, education and the available support structure all had an important role in the decision to continue or stop antibiotic treatment. In the Senate and Brentwood facilities Stein found that statements of encouragement from family and friends were most common among those who completed the full antibiotic regiment and were "far less common" among those who did not complete the full sixty day treatment. [13] Among Brentwood employees repeated visits by health officials and the ability to ask questions resulted in greater use of antibiotics. [17]

The delayed detection and perceived lower risk at the Connecticut facility appears to have influenced the approach used by Postal Service and union officials to communicate with potentially exposed workers. They conducted "town meetings in an effort to reassure postal workers, while still emphasizing that a period did occur when spores were in the air." [12] As already discussed, the Connecticut facility had the lowest use of antibiotics reported in the surveys.

The importance of public health and primary care physicians was also highlighted in Stein's surveys where;
"Of participants who reported that their physician told them to take the medication as directed by public health officials, all but one did so. In contrast, of participants who reported that a private physician did not "clearly advise them to adhere to public health recommendations" either by being vague about the public health recommendations regarding antibiotics or contradicting the recommendations, fewer than one in five took the antibiotics as recommended." [13]

The relationship with public health officials will be discussed further, but the affect of medical experts must be recognized. The good news is that effective communication and support from doctors seems to have a significant positive influence on use of antibiotics. However, the Anthrax attacks were relatively limited and large numbers of resources (relative to the exposed population) were available.

One must question if the same level of support would be available in a mass casualty event and what impact that would have on antibiotic use and untimely the number of casualties.

Observations on the Anthrax Vaccine

Another source of data that can be used to gauge the acceptance of countermeasures uptake is the response to the Anthrax vaccine by U.S. military personnel. The Anthrax vaccine had been in use for many years, but became famous when members of the military began to refuse the vaccine. Use of the vaccine was challenged in court, twice resulting in injunctions against its use. The vaccine was subsequently administered under FDA emergency use rules, and is currently mandatory for personnel deploying to high risk areas, but voluntary for other military members. [18]

Resistance to the vaccine by military personnel is significant for many reasons. First is reflected in the linkage of personal risk and countermeasure acceptance as observed in postal workers. If any population can be considered high risk for the exposure to biological weapons it is the military, so military personnel should be motivated to receive protection. Second, military members can be legally (at this time) ordered to receive the vaccine. For military personnel the negative incentives associated with vaccine refusal are far greater than for civilians. The fact that members of the military population refuse the Anthrax vaccine is concerning when making predictions about behavior of the civilian population.

The response of personnel at Dover U.S. Air Force Base, Delaware serves as a case study for public reaction to a vaccination campaign. The vaccination effort at Dover was uneventful until an article appeared in *Vanity Fare* magazine citing anonymous military members stationed at Dover who were experiencing medical complications they claimed were caused with the vaccination. A link between Gulf War Syndrome and the vaccine was also proposed, as were accusations of vaccine contamination and the presence of additives (squalen). Rumors and resistance quickly spread among the base, and at the height of the situation members were even handing out anti-vaccine literature at the front gate. [19]

In efforts to restore faith in the vaccination program officials tried a general education campaign through town hall meetings. These meetings were characterized as "high risk, low reward" for the presenters as many in attendance were unlikely to be swayed and in some cases the meetings turned into adversarial shouting matches. [19] These meetings appeared to have little impact on the vaccine controversy.

It was eventually recognized that the best results were obtained by general education, with strong support from the medical community especially from primary care providers. It was found that the providers, who were most willing to listen, provide support and continue to investigate concerns had the best results. [19] While this may provide an encouraging model to be followed in public medicine, it is also worrisome in that the military population was relatively small, dedicated free healthcare was available for the military, and there was minimal time constraint on the situation. Similar conditions may not exist in a large scale, civilian attack.

The military currently utilizes the Anthrax vaccine for members deployed to high risk areas. Although it is mandatory, the military is still working to catch up from the various legal issues. Surveys conducted in 2009 showed that only 40.6% of personnel had received all the required Anthrax shots, 16% had received some shots, while 28% had declined. [18] This is roughly equal to the vaccination rate of 50% reported during the period where vaccination was entirely voluntary.[20] This is also lower than the 89% rate Dover was able to obtain when the vaccination was mandatory. [19]

Of current military members older members, and members of the Army were the most likely to have received the vaccine. The most significant indicators for not receiving the shots were concerns with vaccine safety, or a general lack of concern/information. [19] The finding of greater acceptance in the Army is consistent with a 2003 study which found only 5 of 10,000 soldiers deployed to Korea refused the vaccine. [21]

The fact that military members refused the vaccine should be an area of great concern for public officials responsible for emergency planning, and can provide several areas they must focus on when preparing local response plans. The "high" number of refusals relative to the nature of the population must not be dismissed, but can serve as a sentinel for the level of distrust inherent in the general population. Officials can also look to the military efforts to generate acceptance of the vaccine (education, communication and role of medical personnel) as key areas that they must address in any plans that involve medical countermeasures for the general public. One confounding factor in military data not applicable to civilians is that some military members have use vaccine refusal as a means to get out of the military prior to serving their full commitment. [21]

Implications for Public Health

The behavior of individuals exposed to the Anthrax letters was similar to what surveys of the general population predict regarding use of countermeasures. A survey conducted by the Harvard School of public health showed 89% would most likely obtain antibiotics, but 39% would not take them immediately. Only two thirds were confident that there would be enough antibiotics at the site. Other concerns included security, exposure while receiving antibiotics, and safely of the antibiotics. [22] These results are important to help estimate casualties from an attack, but also represent areas of focus for public health officials.

Generating trust in both the government's ability to handle and attack, and the countermeasures themselves represents a large challenge for public health officials. While there is a general trust of public health policies in this country, officials still face a

certain amount of resistance. While there are numerous e-mails and web sites that question every new drug, there are also professional refereed journals that continue to question countermeasures from the Anthrax and smallpox vaccines to Gulf War Syndrome. [23] Compounding the need for communication to build trust, in the event of an attack communication and response efforts may also be hampered by competing interest between health and law enforcement officials[24] which may make the government response appear less than well coordinated and effective.

There is also a small but significant underlying level of distrust by the general public in medicine itself. Distrust of the MMR vaccine in the United Kingdom resulted in a 10% decrease in vaccination rate, with an increase of measles from approximately 50 cases in 2005 to nearly 1000 in 2007. [25] Release of the H1N1 swine flu vaccine was also met with several e-mails warning of side effects. Adding to potential reluctance by the public is the policy of the government to include experimental" (requiring emergency licensing from the FDA for use in emergencies) drugs in its response plan. [26]

Effective communication of the threat and those exposed is paramount and is recognized in the literature as demonstrated by subjects such as; "Provide Information, which is as important as providing medicine" and "Assume the public will not take the pill if it does not trust the doctor". [27] An effective use of communication was demonstrated when the Australian military faced issues over the Anthrax vaccine. The military used trusted and nationally known senior leadership to mount a communications campaign. In addition to education military leadership publicly took the vaccine and media coverage changed from supporting the military to supporting the vaccine. [28]

Communication between public officials and postal workers in 2001 cannot be characterized as effective. Postal workers related instances where they learned of their exposure from the media vs. an official which was compounded by the fact that many initial reports were factually incorrect. [13] Interviews reported that initial views of public health officials were positive, but as they began to view the response as "confused and disorganized" they lost confidence. [13]

Even worse than providing poor information, inefficient communication can cause situations where different populations feel they are treated differently and even feel discriminated against. Thirty three Brentwood employees reported media as their initial source of information (most common response) which contrasted Senate workers who cited internal communication such as the Capitol Physician's Office. [15] Brentwood workers also seldom mentioned any type of advocate and became angry with the lack of results from nasal swabs. [13]

Ultimately the lack of organization and communication cost health officials the respect of the victims, which degraded the countermeasure campaign. One quote from a Senate member characterized this distrust "This 'circus of specialists' came through and said that they had 'seen hundreds of cases of Anthrax, and everything would be fine.' Hundreds of cases of Anthrax? Where? In goats? It wasn't helpful or trustworthy when people were clearly bluffing." [13] The lack trust became so deep some members of the Brentwood facility began to believe they were receiving substandard care because of their race and all four focus groups raised the specter of the Tuskegee syphilis experiments. [15] Other studies identify issues of race and trust as well. Surveys of public attitudes towards public health and bioterrorism in Los Angeles indicate overall 72% feel the response will be fair but it is only 63% among African Americans. [29]

A final confounding factor that must be considered by public health is the behavior of the emergency response personnel. In a simulated attack utilizing rift valley fever 95% of responders would stay on the job, however only 78% of spouses wanted them to remain on the job. This is significant in that a slim majority cited family and loved ones as keys to remaining on job. Additionally 26% considered quid-pro-quo of vaccine for their family as a condition to remain on job. Compounding the effort to communicate and educate the population, the exercise showed journalists had the least knowledge about the event and was the most likely to stay away from the event. None of participants would base decisions solely upon government supplied information. [30]

Conclusion

Both exercises and real world events demonstrate that a small but significant percentage of the population will most likely not utilize available countermeasures. Both sources of data indicate that about ten percent of an affected population will not take countermeasures if available, and that another 10 to 30 percent may take possession of countermeasures but will wait for additional stimuli, such as symptoms in self or others, prior to initiating treatment. Given that countermeasures will most likely not be available for at least a day after an attack timely implementation of countermeasures when received becomes critical. Every one percent that does not take countermeasures could easily become hundreds of additional casualties in a large scale release. Examining the behavior of postal workers and attitudes reflected in public research it may be realistic to expect up to 40% of the population may not take adequate steps to protect themselves from an attack.

The data that are available highlight important public behaviors must be addressed in any emergency response plan to maximize countermeasure effectiveness. The amount of concern or fear that the individual has been exposed to an agent appears to have a strong influence on their use of countermeasures. However, the most compelling evidence cited in the post office workers was positive nasal swabs, or possibly positive hits on postal machines. The implications for a large scale attack are that nasal swabs may be impossible on all potentially exposed individuals. Warnings will most likely be general and conservative (overestimating) when identifying who

was exposed and may not create the personal fear needed to start and maintain antibiotic treatment. The significant question is, will the public internalize sufficient fear from warning such as, “anyone who was in the Pentagon Metro station over the last 5 days may be at risk for exposure to Anthrax?”

It is possible to argue that the postal workers do not represent a real mass exposure situation, because the postal attack was limited with relatively few deaths. The data indicate that person assessment of risk plays a large role in use of countermeasures. There is no doubt that if large numbers of individuals start to die the public demand for antibiotics will greatly increase. However, the concern must be in the 2-4 day period post detection and prior to symptoms when the only reason to take countermeasures will be government warnings. In a large scale attack will the fear of the unknown and the resulting panic result a greater acceptance of antibiotics than those seen in postal worker? This is possible, but the most troubling attitude may be the one of “obtaining antibiotics just in case,” or waiting for symptoms to initiate prophylaxis. In the case of an attack with Anthrax, most individuals who exhibited this attitude would most likely become casualties.

Ultimately the only way to truly know the prophylaxis rate is in the event of an actual attack. However, postal workers and military personnel have demonstrated that there will be a percentage of the population which will not respond as desired. For planners and responders this means they must take every effort to understand and combat these factors, and unfortunately must account for this factor when calculating casualties and estimating medical requirements.

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More Than Just Breaking Things… The 20th Support Command Nuclear Disablement Teams in Action

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The Nuclear Disablement Teams (NDTs) represent a unique capability for the U.S. Army. The NDTs possess the ability to conduct surveys of an area, facility or building for nuclear and radiological hazards, they can conduct on-site assessment in a high-hazard environment, provide initial laboratory analysis and as needed, disable nuclear weapons infrastructure. NDTs provide a Combatant Commander, Joint Force Commander or Ground Component Commander a well equipped, cross functional team that has the training to plan and execute a unique and high-visibility operation. The NDT is an 11 person team with multiple skill sets including Nuclear and Counterproliferation, Explosive Ordinance Disposal (EOD), Chemical and Health Physics experts. The NDT is augmented by communications, laboratory and intelligence experts. The NDT, when fully augmented is equipped with state-of-the-art radiological and chemical detection equipment, laboratory analytic equipment and command and control tools.

NDT Initial Entry Team (IET) team member gains entry to a suspected lab.

Recently, NDT personnel spent two weeks at the Department of Energy (DOE) Oak Ridge National Laboratory and the nearby Y-12 National Security Complex for Operation Hardtack-Poplar. The team spent 13 days training on the NDT mission and refining team level tactics, techniques and procedures for nuclear disablement. The team spent the 1st week in an Oak Ridge National Laboratory classroom environment learning the intricacies of the gas centrifuge and the principles behind centrifuge enrichment. The team then moved to the Y-12 compound and established its command post, analytical laboratories, hotlines, and prepped its vehicles and equipment for operations. Once equipment checks were completed and all communications were in order the team was ready to begin the hands-on portion of the operation.

NDT Structure and Capability

The NDT utilizes several sub-elements to execute its mission. The primary sub-teams are: Initial Entry Team (IET), Contamination Control Team (CCT), Characterization Team (CT) and as needed a Disablement Team (DT). Additionally, there is a Command Post (CP) element which includes the team chief and operations officer along with communications specialists and maintenance support. All sub-elements have secure handheld communication for

NDT Characterization Team (CT) members make an initial assessment.

CT Team collect samples of high interest items.

coordination on-site; team members also carry digital cameras and handheld computers for recording and documenting a facility. Given the environment the team members work in, determining the appropriate personal protective equipment (PPE) level is essential. NDT utilizes industry standard PPE to include disposable protective clothing, gloves and overshoes as well as full face respirators. The team also possesses several Level A PPE kits which is the highest level of protection from vapor, gas and liquid and includes a self-contained breathing apparatus.

The NDTs also possess a wide variety of nuclear and radiological detection equipment. This equipment spans from aerial and vehicle mounted systems, to backpack/ manportable and handheld systems. The vehicular systems include the Airborne Radiological Detection Monitoring System (ARDIMS) pods which can be carried on UH-1 and UH-60 helicopters to provide the NDTs a wide areas search capability. The Vehicle Mounted Detection Systems (VMDS) has 2 versions which mount on a HMMWV trailer or M-Gator vehicle. These systems allow for a closer in survey of buildings to determine those with elevated radiation readings. The backpack and manportable systems allow for point survey of a particular room or piece of equipment or material. The handheld detectors are also used to check equipment but are mainly used to survey personnel for contamination once they have been inside a suspect facility. All of the detectors minus the handhelds are lined into the CP via the Mobile Field Kit (MFK) which allows for near real time reading and spectroscopy in some cases.

The IET has the task of first entry into a suspect building, the IET does an exterior survey and also attempts to determine interior hazards, especially the quality of the air inside. Once this initial survey is done the IET will select its PPE level and enter the building, the IET will do a deliberate search of the interior-looking for hazards and making an initial assessment of what the facility purpose. After this initial survey the IET will call back to the CP and call for the CT to come forward. The CT will do a thorough and deliberate search of the building. The CT will collect numerous samples, take pictures of high interest items and collect documents and material of intelligence value. The samples will be brought back to the command post and the CT will begin an initial confirmatory analysis. The CT can be augmented be an element form the 20th Support Command (SUPCOM)(CBRNE) Analytical and Remediation Activity (CARA). The combined CT and CARA team will produce a detailed chemical and spectrographic analysis. Depending on the size of the buildings and overall size of the facility, this process of on-site survey work and laboratory analysis could take a number of weeks.

Once each building has been surveyed and assessed, the NDT will set to work developing a disablement plan. This plan will take into account guidance from higher headquarters

CT take inventory of suspect materials.

Suspect materials are further analyzed.

and how disablement actions impact the surrounding area. Given the nature of nuclear weapons production, the facilities needed to produce them represent heavy industrial infrastructure and large amounts of the most dangerous chemical and radiological hazards known. Security of nuclear weapons material as well as the safe near-term disablement of the supporting infrastructure is the primary focus of the NDT. Long-term disablement is a deliberate process and one that will eventually be turned over to a military or government contract entity.

The Future

The 20th SUPCOM is establishing a total of four Nuclear Disablement Teams in accordance with U.S. Army guidance and the Quadrennial Defense Review (QDR) of 2010. Both teams will be fully operational by the summer of 2010. The NDTs utilize DOE facilities because they are able to replicate the nuclear weapons infrastructure and likely operating environment that the NDTs may face. Additionally, the DOE facilities have radiation training sources that allow NDT members to practice using their detection systems. This is critical as NDT members must be proficient in their ability to quickly and accurately identify nuclear and radiological hazards in order to ensure appropriate precautions are in place for team operations.

The NDTs have ongoing work with the Defense Threat Reduction Agency (DTRA) Nuclear Detection Division to continuously improve detector capabilities. The NDT recently spent several weeks at Idaho National Lab testing the ARDIMS pod which provides the team an aerial search capability. This new system coupled with the teams vehicle mounted systems expands the NDT search or survey capability. The team is also working with DTRA to improve the Mobile Field Kit for better command and control. All of this means that the NDT can do much more than just break things.

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The Size of One Nanometer?

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Introduction

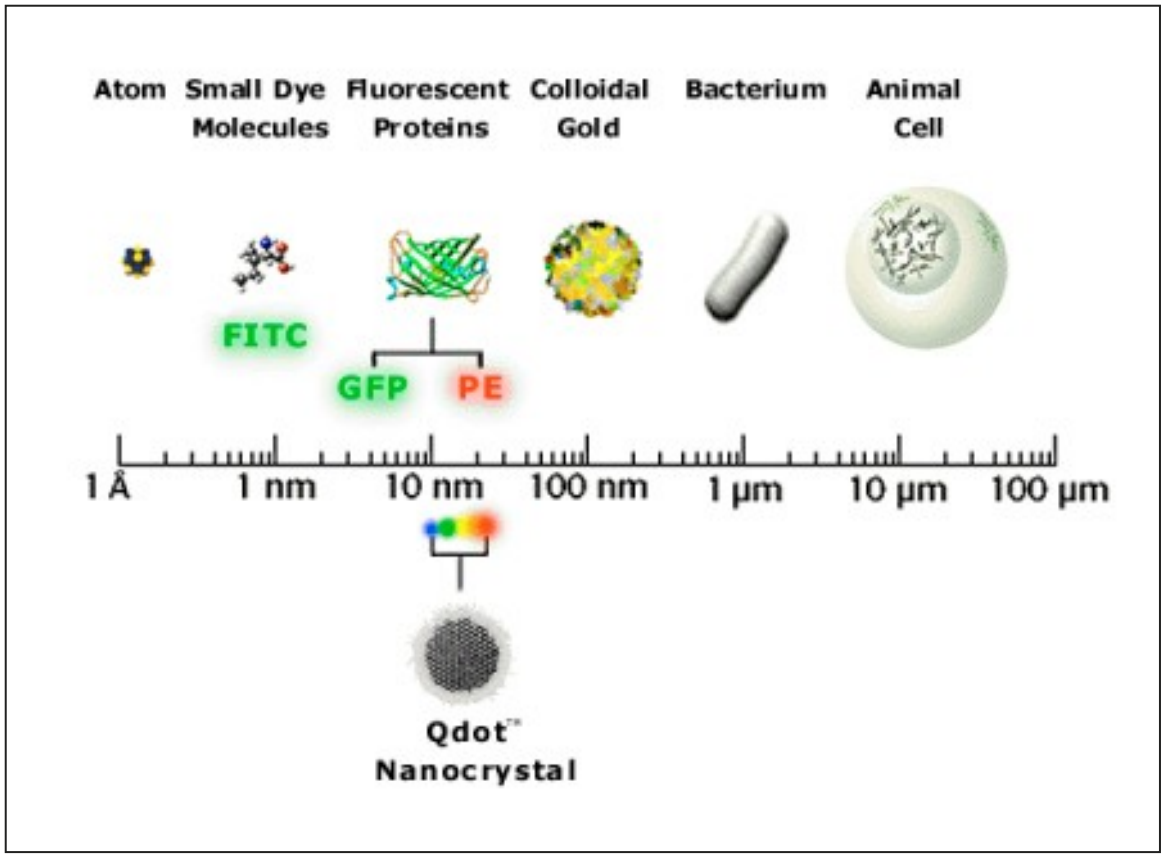
In the space of a few years, many sci-fi ideas seem on their way to becoming reality. Communication systems the size of Dick Tracey's watch or Star Trek communication pendants are almost here, while near non-invasive treatments of serious medical problems are not far behind. All these and many other engineering applications are due to the rapid emergence of nanotechnology. Just how low can we go? To talk about extremely tiny sizes, science has adopted very small units.

Let's begin with the term nanotechnology. Wikipedia says "Nanotechnology is the understanding and control of matter at dimensions between approximately 1 and 100 nanometers, where unique phenomena enable novel applications."[1]

And just how small is this? A nanometer (nm) is one-billionth of a meter, or 10^{-9} meters. To give you a feeling for this length, a sheet of paper is about 100,000 nanometers thick; a single gold atom is about a third of a nanometer in diameter. A nanometer is also about the width of 10 carbon atoms laid side-by-side. One nanometer is also equal to 10 Angstroms, the Angstrom being the internationally recognized non-standard unit of length. One Angstrom is less than the diameter of two hydrogen atoms placed side-by-side. Finally, a micrometer (μm) is 1000 nm.

Possible Applications

As you can see one-atom-thick planar sheets of carbon atoms (sometimes called graphene) can be very thin, and when rolled into nanotubes they can have extremely small diameters. Such small feature sizes allow engineers to create sensors that can be integrated into many military



FITC – fluorescein isothiocyanate GFP – green fluorescence protein PE – phycoerythrin

systems, including uniforms. Several other applications come to mind that would significantly reduce the weight a soldier must carry (it is not uncommon for a soldier to carry 50-75 pounds of gear) yet increase his/her fighting effectiveness. Some of these applications include: weapon, systems, body armor, Command, Control, Communications, Computers and Information (C4I), batteries, and medical supplies.

Consider a small military force of the future. It will be extremely stealthy, capable of being dropped off near or behind enemy lines and execute its mission with no support. To do this, all members must be in constant contact with the team leader and must know what time it is and where each unit member is. They must carry light armor and weapons, and wear smart uniforms that contain communications, computers, sensors, energy packs and medical monitors. The use of nanotechnology would improve a wide range of military equipment:

Weapon systems – lighter, longer lasting weapons and more penetrating ammunition can be constructed from nano materials.

Body armor – vehicles, aircraft, helmets and body armor can be made stronger and lighter than conventional equivalents with nanotube yarn.

Uniforms – camouflage properties similar to those of an Octopus, able to change and adaptive to a host of environmental patterns.

Communications – the *2008 Combating WMD Journal, Issue 1* reported on the development of a working carbon nanotube radio.

Computers – carbon nanotubes could be used to make small computers that could be woven into uniforms. Graphene sheets could be used for display screens.

Sensors – recent Defense Advanced Research Projects Agency (DARPA) studies show that relatively dumb microbots could be distributed over the battlefield to provide substantial battlefield info.

Energy packs – power requirements for nanotube technology could be integrated (woven) into military uniforms.

Medical monitors – Military uniforms could be used to monitor the wearer's health. It could identify the presence of allergens. If injured, information on the wearer's injuries could even be relayed to medical units in the rear and could be used in the meantime to staunch blood flow and sterilize wounds.

Scanners – terahertz-ray (T-ray) scanners could be used in medical and airport scanning devices. Is this the forerunner of the "Star Trek" Tricorder?

And to increase the thermal insulating properties of uniforms, they could be layered with aerogel, a solid material that not only has the lowest known density, it is the best insulator known. It is created by replacing all the liquid in a gel - usually silica gel - with gas, by means of supercritical drying, a process similar to freeze-drying. This creates a nanofoam, a foam with most of its bubbles under 100 nanometers in size, giving the aerogel its unusual properties.[2]

Andre Geim and Konstantin Novoselov (Nobel Prize winners in physics in 2010) started something with their initial scotch-tape experiments. Who would have thought taking a thin layer of graphene off a block of pencil lead with scotch-tape would have accelerated the development of so many innovative applications of nanotechnology?

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Electromagnetic Threats to the National Power Grid (NPG): An Update

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Editor's Note: The original article appeared in the Winter 2010 edition of the Army Chemical Review. Both articles reflect the findings and opinions of the author and are not meant to identify the position of the Department of Defense (DOD), Federal Energy Regulatory Commission (FERC), or electric power industry. First, the articles describe a typical power grid. Next, they identify the basic elements of the U.S. National Power Grid (NPG). Then, they identify potential NPG vulnerabilities and discuss the importance of protection options for specific types of electromagnetic (EM) threats. These vulnerabilities are also discussed from a political standpoint. This article provides an important update to the original political discussion.

Introduction

The National Power Grid (NPG) is a fundamental part of the U.S. infrastructure. Without it the national economy would fail and the results on the civilian population would be catastrophic. Such an occurrence is a real possibility, since the NPG continues to be vulnerable to a wide range of natural and man-made threats. Damage to key nodes in just a single region could take months, even years, to resolve, and during such a shutdown, the regional grid would not provide essential electrical power to process and refrigerate food and medicine, pump fuel/water/sewage, assure communications, maintain bank and stock market records or other critical databases, or even provide light, heat, and air conditioning. In other words, society in that region would disintegrate [Further Reading 1]. If the threat were multi-regional, as it clearly could be, it would cause a national disaster.

While the NPG vulnerability to different kinds of EM threats has been the subject of numerous technical assessments, only recently has it become a national political issue. Congress now has the political will to address this issue in separate House and Senate bills that explicitly identify the most serious EM threats as cyber attack, naturally occurring EM pulse (EMP) caused by solar storms and lightning, non-nuclear EMP (also known as intentional electromagnetic interference (IEMI), and nuclear EMP. No longer do they believe that one of these events might materialize; they now agree it is only a matter of time until it happens.

What is a Power Grid?

A power grid is an enormous power generation, transmission, and distribution system. It consists of: (1) thousands of coal, hydro, natural gas, and nuclear power plants that generate medium-voltage (several thousand volts (kVs)) electric power which is sent to step-up transformer substations, (2) high-voltage transmission lines that take the stepped up high-voltage (hundreds of kVs) electric power and pass it on to (3) distribution centers with substations that then reduce (step down) the voltage and redistribute the electrical power via medium-voltage (1 to 100 kV) and low-voltage lines (below 1 kV) (either above ground or below ground) to such government and commercial users as military facilities, businesses and homes. A typical grid is shown in Figure 1 [Further Reading 2 and 3].

In its simplest form, a power grid does not store the power it generates. Every bit of that power is immediately distributed throughout the connected system (electricity coming out of a wall socket was generated less than a millisecond ago). This means power plants must constantly generate an enormous amount of power to accommodate grid losses and power usage spikes. These grid conversion and transmission losses could be substantial: for generation facilities that have high combustion and heat losses due to the use of older boilers and turbines, as little as one-third of the total power produced might eventually be delivered to the user.

Since most industrialized nations have grids that consist of these three

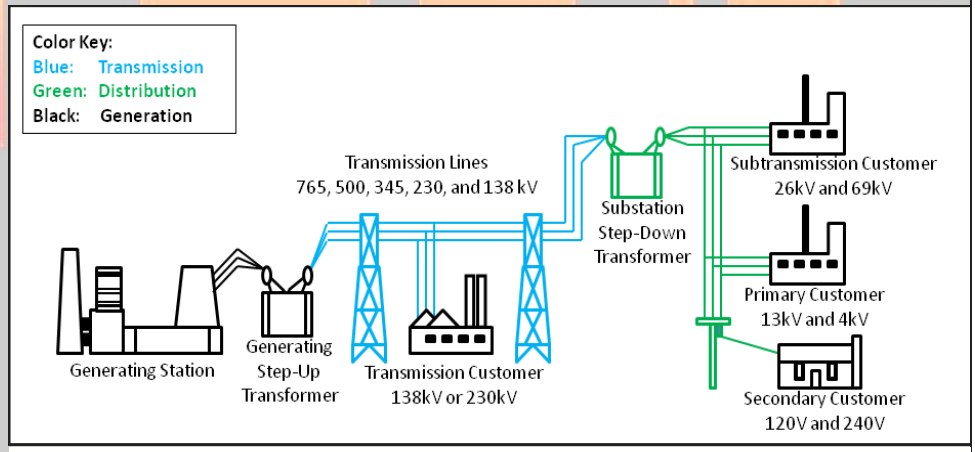
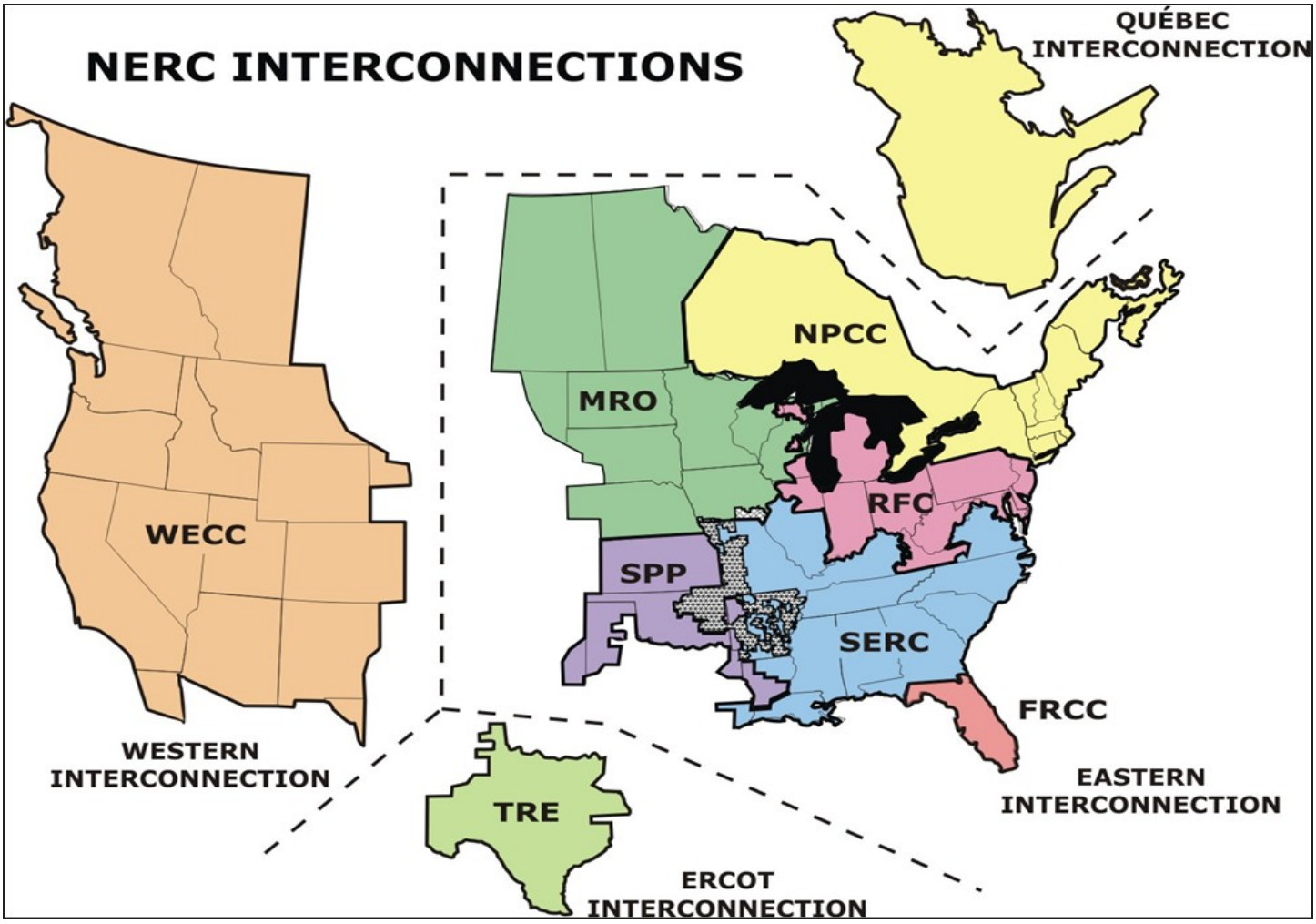


Figure 1. Typical electric power grid.



North American Electric Reliability Corporation (NERC) regions.

FRCC - Florida Reliability Coordinating Council
MRO - Midwest Reliability Organization
NPCC - Northeast Power Coordinating Council
RFC - Reliability*First* Corporation
SERC - SERC Reliability Corporation
SPP - Southwest Power Pool, RE
TRE - Texas Regional Entity
WECC - Western Electricity Coordinating Council

Figure 2. The three interconnections of the U.S. National Power Grid and the Eight North American Electric Reliability Corporation regions (NERC).

basic parts, it is reasonable to assume that the discussion on NPG vulnerability applies to other national power grids, although exact sensitivities vary due to system-level differences.

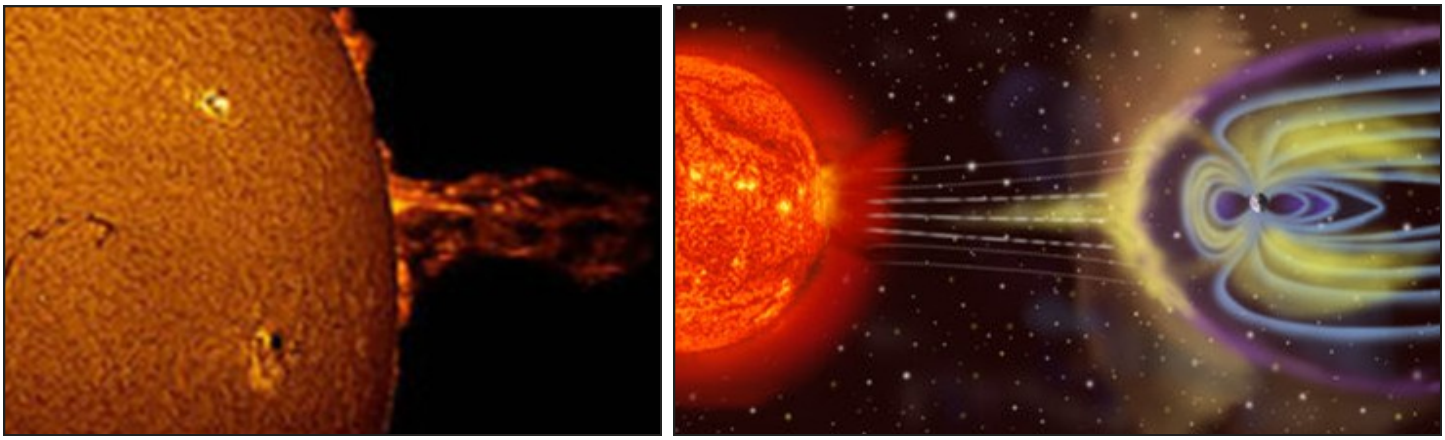
What is the NPG?

The NPG is a complex network of *independently* owned and operated power plants, transmission lines, and distribution subsystems interconnecting the continental U.S. Although this network is not owned by the U.S. government, as a natural monopoly it is regulated by the government. This means the government has the authority to *regulate* electric power as a commodity and *ensure* network reliability.

Figure 2 shows that the NPG consists of three interdependent but separate networks:
The Eastern Interconnection,
The Western Interconnection, and
The Electric Reliability Council of Texas (ERCOT) Interconnection.

Besides their connection to each other, they are connected to the Canadian and the Mexican grids, forming the North American Power Grid. A clear illustration of the NPG and its eight North American Electric Reliability Corporation (NERC) Regions is provided in Further Reading 4. NERC and others have completed NPG vulnerability studies and have proposed ways to protect it against some of the more serious EM threats. [Further Reading 5]

It is important to emphasize that the NPG has grown over the years to accommodate an increasing population with a growing appetite for electrical energy. Today, 40% of the energy consumed in the U.S. is used by the NPG to produce electricity (in 1940, it was 10%, and in 1970 it was



a. CMEs leaving the Sun.

(b) CMEs interacting with Earth's Geo Field.

Figure 3. Typical solar activity.

25%). [Further Reading 4] The NPG now consists of a patchwork of old and new power plants, transmission lines and substations tied together over many years to form the three separate networks mentioned above. The continued expansion of the grid to meet the increasing power needs has had the unintended consequence of slowly increasing grid vulnerability to EM threats.

NPG Vulnerability:
A Technical Assessment

NPG vulnerability has been studied and documented by numerous organizations, both in the private sector and the DOD. One study, begun in 2001 by the House Armed Services Committee, looked at NPG vulnerability to a specific type of nuclear-generated EMP [Further Reading 5]. Other studies looked at actual regional shutdowns due to several different threats including naturally occurring EMP and even personnel error. Their conclusions are the same as the others: either upgrade the existing NPG or start over.

Three of the more recent regional shutdowns of the NPG were the result of naturally occurring EMP caused by multiple lightning strikes on transformers (New York blackout of 1977), a localized solar storm (Quebec, 1989), and an operational control problem in what is referred to as "The Lake Erie Loop" (Midwestern U.S., Northeastern U.S., and southern Canada, 2003). In the first two, the results were of modest intensity (compared to the massive solar storm of 1859) and the loss of power was somewhat controlled. Nevertheless, the economic cost ran into the hundreds of millions of dollars with portions of the grid down for weeks. The March 1989 solar storm cost two large utilities, Hydro-Quebec in Canada and Public Service Electric & Gas (PSE&G) in New Jersey, an estimated $30 million in direct costs. Hydro-Quebec also spent $1.2 billion on installing protection devices to block future storm-induced currents. In one recent assessment, the Quebec solar energy field strength (about 5 volts/kilometer (V/km)) and duration (several minutes) was shown to compare favorably to the late-time field strength and time duration characteristics of a nuclear-generated high-altitude EMP (HEMP) [Further Reading 6]. This means HEMP also has the capacity to knock out portions of the NPG. If either natural or nuclear-induced EMP were to damage one of the custom-ordered 500 kV 1200 megavolt-ampere transformers, it likely would take more than a year to replace since most of these hand-wound extra high voltage transformers are today made in China, India, Japan and Europe.

Unlike the unpredictability of a nuclear-generated HEMP event, solar storms, due to an 11-year cycle of solar activity, are cyclical. Many times during each cycle, the sun ejects a stream of charged particles (called coronal mass ejections (CMEs), some of these are recaptured by the sun while others stream into space (Figure 3(a)).

Those that travel toward the earth in the enhanced solar wind are eventually captured by the earth's magnetic field and bent, causing the flow of charged particles downward toward the lower ionosphere (approximately 100 km altitude) where they eventually produce a horizontal current flow (Figure 3(b)).

As these particles travel downward, they produce a visible glow through various ionization processes. In the northern hemisphere, this aurora phenomenon is known as the Northern Lights (Figure 4(a)). It is also similar to the glow seen in the upper atmosphere after a high-altitude nuclear detonation due to the flow of charged particles from the nuclear detonation (Figure 4(b) page 25).

The current solar cycle #24 (as described by the sunspot number) is predicted to peak around 2013. While no one can forecast how serious it will be, it is reasonable to assume that this or one of the future solar cycles will produce a storm that will rival or exceed the 1-2 September 1859 storm, sometimes referred to as the Solar Superstorm or the Carrington Event. This killer storm was the strongest ever recorded. It has been estimated to be many times the strength of the 1989 regional storm over Quebec, and even though it caused less damage to the rugged

(a) Northern Lights.

(b) STARFISH U.S. high-altitude nuclear test conducted in 1962 near Johnston Island in the mid-Pacific.

Figure 4. A comparison of Northern Lights to Johnston Island nuclear detonation.

and primitive1859 electrical systems than more recent storm damage to electronics and electrical systems in Quebec, it still caused fires and the failure of telegraph systems over Europe and North America. In addition, auroras caused by the 1859 storm were seen around the world as far south as Cuba, and over the Rocky Mountains the sky was so bright that the glow woke up gold miners [Further Reading 6 and 7].

Another major threat to the existing NPG is a cyber attack or some other form of information attack. The NPG. like many modern systems , is computer controlled and net-centric and potentially vulnerable to compromise. Unlike natural and nuclear-generated EMP, which cause immediate and detectable catastrophic damage or unacceptable upset to the NPG, an information attack could go undetected for some time.

In an effort to minimize protection costs, treating cyber attacks (usually in band with the electronics operating frequencies and at normal operating levels) as another EM threat is the preferred approach of the author. To accomplish this for the least cost, the EM Environmental Effects (E3) and Electronic Warfare (EW) protection communities must be integrated and a unified protection scheme must be part of a new system design. This protection must then be maintained throughout the NPG lifetime. A discussion on addressing E3 and EW protection together was the subject of a recent article in the CWMD Journal [Further Reading 8].

NPG Vulnerability:
A Political Assessment

Political support for the protection of the NPG is again growing. In late 2009, tri-lateral support pushed forward bills in both the Senate and the House. Representative Yvette D. Clarke (D-NY), Chairwoman, Subcommittee on Emerging Threats, Cybersecurity, Science and Technology, and Representative Roscoe G. Bartlett (R-MD), member of the Armed Services Committee, supported House Resolution (H.R.) 2195. Senator Joseph Lieberman (I-CT) supported Senate (S.) 946. Both bills propose "To amend the Federal Power Act to provide additional authorities to adequately protect the critical electric infrastructure against cyber attack, and for other purposes." Other electromagnetic threats emphasized in the bills are EMP caused by both solar storms and nuclear detonations.

At about the same time, The House Energy and Commerce Committee's Subcommittee on Energy and Environment held a legislative hearing on H.R. 2195 and another bill (H.R. 2165, the Bulk Power System Protection Act of 2009) intended to protect the grid from cybersecurity threats. This hearing was followed by a classified briefing to Members of the Energy and Commerce Committee by Administration officials on threats to the electric grid. Since then Majority and Minority staff members for the Energy and Commerce Committee worked to develop a bipartisan discussion draft to amend the Federal Power Act to "…give the Federal Energy Regulatory Commission (FERC) new authorities to protect the electric grid against cybersecurity and other threats as well as from geomagnetic storms created by solar flares." This bill (H.R. 5026) passed the Energy and Commerce House Committee on March 9, 2010 by a vote of 47-0 [Further Reading 9] and then passed in the House by a voice vote on June 9, 2010. On September 27, 2010 the bill was placed on the Senate Legislative Calendar under General Orders. Calendar No. 617. H.R. 5026 is now referred to as the "Grid Reliability and Infrastructure Defense Act" or the "GRID Act."

Should Congress approve a single bill, the question becomes just how robust one must make the entire NPG or the most critical parts of it. Either way, the cost is significant. Making it more robust has led to several ideas, including the redesign of the NPG into a commercial digital Smart Grid regulated by the FERC and capable of energy storage [Further Reading 10].

Until a permanent solution is funded, the DOD must consider options that assure their continued ability to complete critical missions.

New York City blackout.

One of these options is the isolation of military posts, bases, and facilities from the civilian NPG. This isolation could be achieved with the development and deployment on each site of modular, small (10-25 megawatt (MW) electric) nuclear power reactors (NPRs). The idea of using small NPRs is not new. In fact, about fifty years ago the U.S. Army used fixed NPRs to provide electrical power to Fort Belvoir, VA and Fort Greely, AK. In addition, mobile NPRs were used at Sundance, WY, Camp Century in Greenland and McMurdo Sound in the Antarctic. And finally, a 45 MW (thermal) NPR mounted on a floating barge (MH-1A Sturgis) provided the Panama Canal Zone with electricity for eight years (1968-1976) [Further Reading 11]. The proper integration of small NPRs into a *comprehensive* civilian and military EM threat protection scheme, including both hardware and software protection could protect Army sites from cyber attack as well as other forms of EM threats.

Conclusion

Both the technical community and Congressional policy makers recognize the vulnerability of the NPG to different forms of EM threats. Technical assessments have identified potential weak points/nodes and have provided protection options. On the policy side, Congressional H.R. 2195, H.R. 2165, H.R. 5026, and S. 946 bills include cyber attack, severe geomagnetic storms, IEMI and EM weapons as significant EM threats. This combination of diverse threats can only be addressed by integrating hardware and software protection into an overall (end-to-end) system design. The integrated protection must then be maintained throughout the lifetime of the NPG. And while the least expensive approach to protecting hardware and software is to include it into the original system design, the existing NPG requires a more expensive form of retrofit protection involving the support and involvement of many private businesses. For this reason, the author concludes oversight for such a massive protection scheme must be the responsibility of one civilian organization, possibly the Office of Electric Reliability, FERC [Further Reading 12].

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Front article picture: City Skyline by CW5 Stephen Gomes

Selection of Simulants for Barrier Material Permeation Testing

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Introduction

Military forces need to assess the performance of equipment, such as masks, tents, or vehicles, prior to deployment on the battlefield. Developmental tests assess the performance of the equipment and operational tests assess how readily personnel can use it. Equipment designed to protect against chemical agents must be tested. For reasons of cost, safety, and to comply with international law, only certain types of testing are performed with toxic chemical warfare agents. All other tests are performed with a substance (simulant) that is expected to have similar characteristics as an agent and is convenient for use in a given test environment. Simulants have been used extensively since World War I. Since the U.S. abandoned outdoor chemical releases in 1969[1], simulants have been used exclusively for field testing of defensive equipment.

To understand the significance of test results performed with simulants and to predict how the equipment will perform when tested with agent, it is necessary to measure the agent to simulant relationship (ASR). For protective equipment, the simplest ASR is the ratio of agent concentration to simulant concentration, when measured concurrently under the same conditions.

The selected simulant must meet the following criteria: (1) a simulant should match the properties of the agent that are relevant to the equipment being tested, (2) the data used to choose the simulant should be reviewed and traceable, and (3) the simulant should be usable in a planned test. Since no individual simulant can perfectly match an agent, input from scientific, operational, and test perspectives must be considered and balanced. A simulant selection process that does not meet the criteria will produce limited or inaccurate test results. Such results will produce misleading conclusions regarding the performance of the equipment against agents on the battlefield.

Simulants have been selected previously for testing protective equipment.[2,3.4] In this study, simulants were selected for permeation. Permeation was chosen because the permeation of agent is a risk to both individual protection (suits, gloves, and masks) and collective protection (tents, ships, and vehicles). Further impetus was provided by a collective protection acquisition program that needed a traceable, validated simulant selection method that was required to base decisions on peer-reviewed technical data, together with well-documented input of subject matter experts (SMEs).

In this project, simulants were selected for four nerve and blister agents. All compounds are liquids at ambient conditions. To understand the permeation of a compound through protective equipment, physical processes were identified and related to physical and chemical properties that could be found in Chemical Abstracts Service (CAS) database[5] and in Beilstein CrossFire Commander [6] database. Values of each physical property were collected for agents and for candidate simulants. Decision models were developed to evaluate candidate compounds to be used as simulants in laboratory, chamber, and field test environments.

In laboratory tests, small amounts (grams) of a compound are used with the appropriate engineering controls to test samples of material and small equipment. For these tests, compound toxicity and cost are less important than its ability to mimic agent. However, in chamber tests larger quantities (several grams) of agent can be used with the appropriate engineering controls to test medium-sized equipment. In contrast to the laboratory tests, a balance between the toxicity of the compound and its similarity to agent is necessary before chamber testing. In open air (field) tests agent cannot be released under any circumstances and generous amounts (kilograms) of simulants are used to test large equipment; cost and environmental safety are paramount. The usability of each candidate simulant for testing was assessed.

Simulants were selected for laboratory testing to validate that the performance of the selected simulants was similar to that of the agent.[7] The

results of agent and simulant tests were compared to establish a pilot ASR. [7] The selection process was successful since the rank ordering of simulants agreed with the model predictions.

Future programs will be able to predict simulant performance against agents, using a well-characterized candidate simulant, an ASR, and a system performance test with simulant.

Methods

Although the process for the selection of simulants was implemented for permeation simulants, it is broadly applicable to other simulant selection testing. The selection process had five stages: problem definition, simulant identification and screening, simulant selection, simulant usability assessment, and simulant validation. The approach was based on established operational analysis principles [8] combined with scientific knowledge of the permeation process. Operational analysis guidance was provided by the Decision Analysis Team at Edgewood Chemical and Biological Center (ECBC). The evaluation methodology utilized a decision analysis process called Multi-Criteria Decision Making (MCDM). Decision analysis and MCDM were based on the established principles of operations research. MCDM was used previously[4] and was relevant for this work. The MCDM evaluation model consisted of a finite set of evaluation criteria, derived from the physical properties and usability factors. The criteria chosen were relevant to the situation being addressed, independent from one another, and distinguished between the different simulants being considered. Commercial MCDM software, Logical Decisions for Windows (LDW, Logical Decisions, Fairfax, VA) was used for model development and to support the assessment process. At each test stage, the number of candidate simulants was reduced to optimally use time and resources for the next stage. A research team was assembled with expertise on operational analysis, agent and simulant chemistry, database searching, and material testing to guide the selection process.

Table 1. Contamination events related to physical properties.

Battlefield Scenario	Event	Physical Properties	Event Weighting
Attack releases droplets of a nerve agent. Droplets settle on a barrier material e.g., rubber.	Drop on surface of air-impermeable material. Agent may evaporate or permeate.	Heat of vaporization, vapor pressure, molecular dipole, and molar volume.	0.2
Attack releases droplets of a nerve agent. Droplets settle on a tent.	Drop on surface of air-permeable material. Agent may evaporate, permeate, or travel through pores.	Heat of vaporization, vapor pressure, molecular dipole, surface tension, and viscosity.	0.2
An artillery barrage stirs up agent-contaminated dust that settles on a tent.	A particle of dust lands on tent fabric. Its size and polarity limit its ability to travel through the fabric.	Particle diameter, molecular dipole.	0.2
Artillery shell releases agent that evaporates. Agent vapor is drawn into the air intake filter in a tent.	Vapor is incident on an activated charcoal filter.	Heat of vaporization, molecular dipole.	0.1
Personnel walk across ground contaminated with agent and then shelter in a tent.	Personnel track in agent or liquid on clothing and boots. A little agent vapor enters the tent.	Molecular dipole, molar density, surface tension, viscosity, and heat of vaporization.	0.3

Problem Definition

The main simulant properties were identified that affected permeation through protective material. Different types of contamination events were defined. Physical processes such as evaporation and diffusion governed each type of contamination event. Information on the rate of each contamination event for a given compound was typically unavailable; therefore, further analysis was used to relate those processes to the physical properties that could be found in databases. Properties were also defined that affected the usability of a simulant in the testing environment. The specific criteria for usability differed between laboratory, chamber, and field environments. The relative importance of each property was determined and given a weight by the research team.

Simulant Identification and Screening

The value of each property (Table 1) was determined for each agent. The chemical literature was consulted to determine the value of each property for each candidate simulant. The initial search returned a large number of candidate simulants that was reduced by screening criteria. Essential steps in reducing the initial search numbers were to obtain missing property values and resolve conflicting data. Candidate simulants with property values close to the agent value were considered for selection.

Table 1. Contamination events related to physical properties.

Simulant Selection

Each candidate simulant was converted to a score. This score was multiplied by the pre-determined weight for that property. The weighted scores were then totaled to yield the utility value for that simulant. Candidate simulants were ranked by utility and the top-ranked simulants were selected for technical assessment.

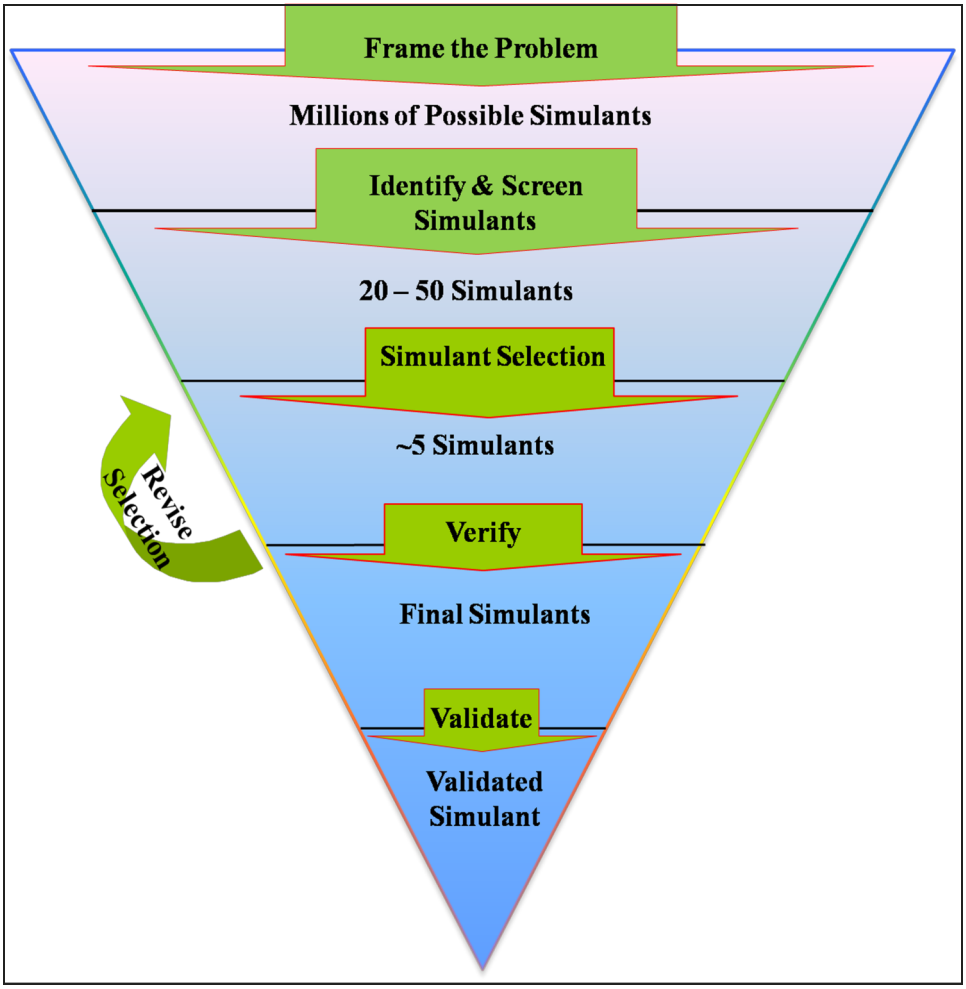

Figure 1. Simulant selection pyramid, showing the selection process.

Simulant Technical Assessment

Each candidate simulant was further assessed to determine if it was technically suitable for field or chamber test environments. Simulants deemed usable were submitted for validation.

Simulant Validation

The selection and usability assessments yielded simulants that were predicted to have permeation characteristics that are similar to agent. The selected simulants and agents were subjected to laboratory permeation testing by determining the permeation rate of each compound through a reference material. Simulants were ranked by how closely permeation rates resembled agent rates. [7]

Results and Discussion

Problem Definition

Once the assessment and validation process was completed for the simulants, the number of possible compounds was reduced to a small number of selected simulants. The process is illustrated in the selection pyramid in Figure 1.

To start the process, it was necessary to frame the problem. Contamination events were defined by the manner in which the contamination might occur on different types of materials that could be found on the battlefield. Materials were classified as semi-permeable (air can pass through material) or as impermeable (air cannot pass through). Five contamination events were identified: drops on semi-permeable materials, drops on impermeable materials, aerosol on semi-permeable material, vapor challenge on carbon filters, and liquid contamination tracked into the tent. Each contamination event is described in Table 1. Contamination events were deliberately chosen not to be specific for any particular type of material.

Each contamination event was mapped to the physical properties found in CAS [5] and Beilstein CrossFire Commander [6] databases. Contamination events that were more likely to happen and/or had a higher consequence to the soldier were assigned a higher relative importance (weighting). The weighting of each event was somewhat arbitrary; however, the conclusions indicate that the choice of simulants was insensitive to the exact event weighting values.

The physical properties corresponding to each test are listed in Table 1. The main physical properties were heat of vaporization, molecular dipole, molar volume, vapor pressure, surface tension, and viscosity. It was determined that the physical properties listed first had more impact on the choice of simulant. Each property was assigned a weighted value, distinct from the event weighted values described in the previous paragraph. Other properties were defined that would affect the ability of each simulant to be used in testing. In MCDM, the evaluation model was structured in the form of a hierarchy. Higher-level criteria, referred to as goals, represented categories of criteria (e.g., physicochemical and usability). The simulants were evaluated against the lower level criteria, referred to as measures. The measures were quantitative in nature (e.g., vapor pressure) or qualitative (e.g., operating conditions). Each measure was defined specifically for the scenario under consideration. The definitions were important to ensure common understanding, so that those conducting the assessment evaluated the simulants as similarly as possible. Usability criteria were defined by team members with experience in testing.

Some simulant properties were defined continuously as a positive, real number. Other properties were defined as discrete values (e.g., high/medium/low). A performance scale was developed for each measure and was used to identify how well a simu-

Table 2. Simulant Properties and Performance Scales.

Factor	Definition	Laboratory and Chamber Performance Scale	Field Performance Scale
Physical/ chemical	The similarity of physical properties between agent and simulant, for each property listed in the text.	100 * the ratio of the properties as defined in Equation 1	
Medical	The potential for adverse health effects presented by the simulant under the conditions of the test. Primarily based on National Fire Protection Association (NFPA) Health Rating (HR). The NFPA HR is an accepted summary of toxicity, on a convenient 0-4 scale, taken from the Material Safety Data Sheet (MSDS) supplied with every compound.	100 – No health effects, minimal safety equipment required: HR 0 75 – HR 1 50 – HR 2 25 – HR 3 0 – Significant health effects if exposed; requires use of full protective suit/mask – HR 4	100 – No health effects: HR 0 75 – minimal safety equipment required: HR 0 50 – HR 1 25 – HR 2 0 – HR 3 or 4
Environmental impact	Effect of the simulant on flora, fauna, and microbial systems. Simulant should not persist in the environment after test, or destroy stratospheric ozone. This work is an estimate, based on the MSDS. The final decision comes from the National Environmental Policy Act (NEPA) assessment.	100 – Expect no impact on environment 50 – Expect some impact 25 – Expect considerable impact 0 – Expect severe impact, cannot be released, or does not degrade	100 – Expect no impact on environment 75 – Expect very slight or transient impact or chemical is not on field-releasable list 50 – Expect slight impact 25 – Expect some impact 0 – Expect considerable or severe impact, or does not degrade

lant performed relative to a specific measure. Values of 100 and 0 were assigned to the upper and lower ends of the scale, respectively, and intermediate values were then derived based on the principles of utility theory. [8] This translated dissimilar information into common units, and allowed for the comparison of scores across different measures. Table 2 lists the properties used for selecting simulants, and the associated scales.

Simulant Identification and Screening

It was necessary to find values for the properties of the agents to compare the similarities of simulants to agents. Agent property values were compiled by the Agent Chemistry Team at ECBC. CAS [5] and Beilstein CrossFire Commander [6] databases were searched for simulant property values.

Over 10 million organic compounds were found, each with unique CAS number. This number was reduced using the following screening criteria: Candidate compounds were to be commercially available liquids; radioactive, extremely toxic, malodorous, hygroscopic, unstable, or reactive compounds were excluded. Other compounds were rejected if they produced toxic or corrosive products in common use, i.e., in the presence of air, water, or light. Because agent molecules do not donate protons (aprotic), only candidate simulants that were also aprotic were accepted, because they were more likely to mimic the interaction of agents with substrates. It was required that all compounds could be detected using the MINICAMS® (a miniature, automatic, continuous air-monitoring system; OI Analytical, College Station, Texas) gas chromatograph fitted with a flame photometric detector; therefore each compound had to contain phosphorus or sulfur. The criteria were reduced to mathematical operators that could be understood by the search software. For example, the liquid criterion was specified as: melting point available AND melting point < 0°C AND boiling point available AND boiling point > 60°C at 1 atmosphere pressure.

Only single compounds were considered. It might be possible to mix compounds to match some agent properties. However, it was considered too complex to tailor a mixture to match many properties of an agent. The theory of mixtures does not allow the confident prediction of all significant properties of a mixture from its composition. Furthermore, mixtures would change their properties during testing because differential evaporation of different components would change the composition. Lastly, mixtures would change composition due to chromatographic separation of composition within the material being tested.

Additional data were obtained from Agent/Simulant Knowledge Database (ASK), a governmental information repository of physical and chemical properties, toxicological data, applications, and environmental fate and effects information. ASK is available from the Chemical, Biological, Radiological and Nuclear De-

Table 3. Property Weightings for a simulant of a nerve agent, for laboratory, chamber, and field testing.

Factor	Laboratory Test Weighting	Chamber Test Weighting	Field Test Weighting
Physicochemical – Heat of vaporization	15	11	3
Physicochemical – Molecular Dipole	20	14	4
Physicochemical – Vapor pressure	18	13	4
Physicochemical – Surface tension	6	4	1
Physicochemical – Viscosity	6	4	1
Physicochemical – Molar volume	13	9	2
Usability – Medical	2	7	16
Usability – Ease of Use/Safety	1	4	7
Usability – Material Compatibility	6	6	10
Usability – Operating Conditions	6	6	10
Usability – Test Operations	5	10	16
Usability – Storage and Shelf Life	0	0	0
Usability – Environmental Impact	0	7	14
Usability – Availability	0	0	0
Usability – Cost	2	5	12
TOTAL	100	100	100

$$Score = 100 \times \min\left(\frac{Value_{simulant}}{Value_{agent}}, \frac{Value_{agent}}{Value_{simulant}}\right)$$

Equation 1

fense Information Analysis Center (CBRNIAC). The ASK user interface permits a chemical agent/simulant comparison search based on properties of interest.

Simulant Selection

Initial searches were performed using the properties for which data were most commonly available in the Beilstein CrossFire Commander [6] database: vapor pressure and liquid density. Only compounds with at least one literature value for each property were accepted (e.g., all compounds having a liquid density within 20 percent of the agent). For each property, a search window was used on each side of the agent value. A wider search window would return more hits. The search windows were varied iteratively to return a manageable number (approximately 200) of compounds that met the criteria.

Paper usability studies were conducted and included cost and availability, thermal stability, storage requirements, interaction with battlefield contaminants, disposal, flashpoint, and explosive limits of vapor in air criteria. Cost and availability were determined from vendors. Other properties were determined from the chemical literature, the Material Safety Data Sheet (MSDS), or by review.

For physicochemical properties, the score was calculated as the ratio of the value for the simulant to the value for the agent, multiplied by 100.[9] If the value for the simulant exceeded the value for the agent, the ratio was inverted before multiplying by 100, to keep the score less than 100. This approach is summarized in Equation 1. The scores were used both to screen simulants, and in the evaluation model to score the simulants: [9]

Discrete properties were converted to scores using the scales in Table 2. The scores and weights were calculated for each simulant and each property. The formula expressed in Equation 2 was used to calculate the utility value for each simulant:

$$U = \sum_i Score_i Weight_i$$

Equation 2

Where the sum was performed over all properties, and the index i was used to label the property. Weights were chosen by the team and were adjusted to sum to 100.

Weightings were defined for laboratory, chamber, and field tests. In addition, weightings were slightly different for each agent. Example weightings are shown in Table 3. Weights were entered directly into the MCDM software.

The MCDM software combined the values and the weights for each property and ranked the simulant by utility value. The contribution of each score and weight for the most highly-ranked simulants is shown in Figure 2. The best match for a blister agent was predicted to be methyl salicylate (MeS, CAS number 119-36-8). An intermediate match was triethyl phosphate (TEP, CAS number 78-40-0) and a poor match was phenyl acetate (PA, CAS number 122-79-2). Simulants 3-hepten-2-one (HP, CAS number 1119-44-4) and trimethyl phosphate (TMP, CAS number 521-56-1) were predicted as the good and intermediate matches for a nerve agent respectively. For another nerve agent, 4-chlorobutyl acetate (CA, CAS number 6962-92-1), TEP, and diisopropyl fluorophosphate (DFP, CAS number 866-23-9) were predicted to be the best, intermediate, and poor matches respectively.

MeS and TEP were ranked in the top five blister agent simulants for laboratory, chamber, and field testing. In addition, TEP is a simulant that is frequently used. Compounds with a cost of US $0.02/gram or less when purchased in bulk are most practical for field use, and the only blister agent simulant candidate that met this threshold was TEP at $0.01/gram. Other blister agent simulant candidates cost significantly more.

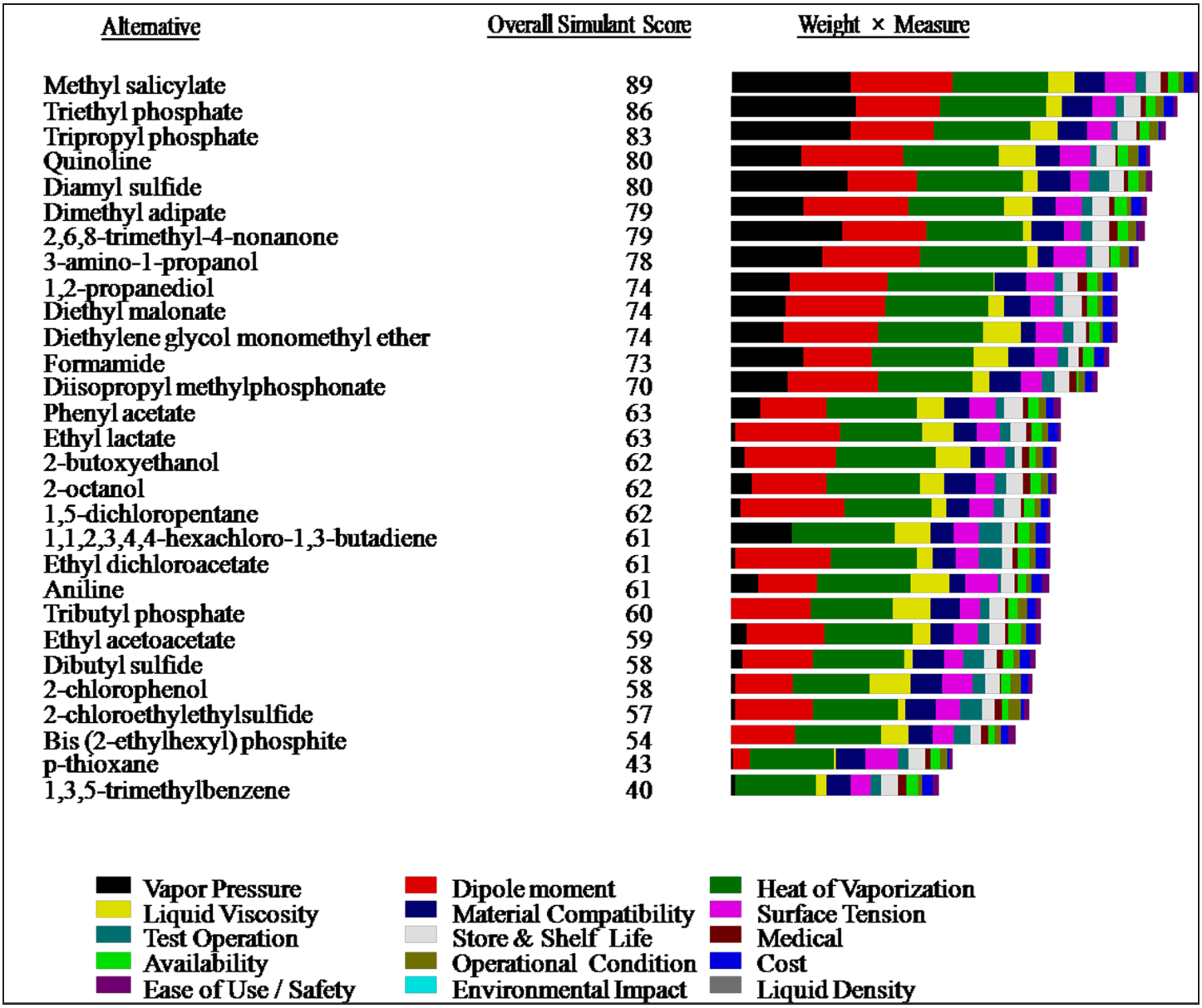

Figure 2. Stacked bar chart showing the contribution of each property to the utility value for the highest-ranked simulants of a Blister Agent for test in the laboratory.

The intermediate simulant PA was also chosen to test the selection process across a wider range of property values.

Simulant Technical Assessment

Technical studies were performed on each candidate simulant to assess whether the simulant would be suitable for use in the test environment. By theoretical analysis, it was determined that these simulants would not react in a hazardous manner with contaminants commonly found in the test or operational environment.[10] Furthermore, the candidate simulants were unlikely to be depleted by reaction with these contaminants. Lastly, it was determined that these simulants could be quantified in the presence of some level of these contaminants during swatch, chamber, and field testing.

Laboratory usability studies included interaction with test facility surfaces (which affected the persistence of the compound on facility surfaces after a test), presence in the test environment, ease of dissemination, ability to be detected at the minimum detection limits needed in testing, interaction with safety monitoring systems, and the ability to be removed after testing.

Simulants were selected by considering different properties. The properties that yielded the most information for selection were those that were highly weighted, and for which the value differed greatly between simulants. Vapor pressure, dipole moment, and liquid viscosity were the most selective physical criteria.

Simulant Validation

The measured ranking of simulants agreed with the predicted ranking, once the properties were weighted more specifically for the reference material. ASRs were successfully established between each agent and at least one simulant

chosen by the selection process. Further details are provided in the validation paper. [7]

Conclusions

Simulants were selected for permeation through protective materials using a documented, traceable process. Peer-reviewed literature data were used, together with commercial data sources, and SME input. The results of the selection operation were successfully correlated to the results of the pilot ASR test [7].

Validation was successful and the selection process was accepted for use by a collective protection acquisition program. Furthermore, a simulant selection Test Operating Procedure was drafted for use by all Department of Defense testing laboratories.[11]

Ongoing work for the acquisition program has selected simulants using revised criteria for the nerve and blister agents. The performance of the revised list of simulants is being determined under different test conditions. The usability of simulants will be assessed in more detail.

Acknowledgement

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Validation of the Chemical Warfare Agent Simulant Selection Process for Barrier Material Permeation Testing

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Introduction

Militaries have a long history of using surrogates to study hazardous materials. However, surrogates for hazardous military chemicals have a relatively recent history, dating from the First World War. Simulants have been used in U.S. weapon development since the 1940s when everything from water to methyl salicylate (MeS) was used, to the 1980s when alternatives were used to assess Russian binary weapons [1]. Simulants selected for offensive programs adequately addressed the primary need at the time; however, less effort was placed on developing simulants for defensive purposes, such as protection, detection, and decontamination [2, 3]. Furthermore, past programs selected simulants to mimic relevant physical properties such as vapor pressure, evaporation, and/or viscosity. In 1969, the U.S. ceased outdoor CWA releases [4]. Since that date, it became necessary to use surrogates, also known as simulants, to reduce the risk of exposure to toxic warfare chemicals during training, developmental testing, and equipment evaluation in field testing [5].

Traditional test protocols, based on historically used simulants, have shown that past simulants had limitations for testing the field performance of equipment that defends the warfighter against CWAs [6]. In addition, limitations placed on the testing of defensive materiel through treaties, regulations, and safety requirements demand simulant correlation with CWAs and relevant simulant selection.

Validated simulant selection is vital to the statistical correlation of simulant performance to CWAs. An improperly implemented simulant selection (due to a lack of relevant physical or chemical property values) will produce simulant field results that either mislead or provide information of limited use. Significant efforts have been made in both simulant selection and testing methods to provide accurate correlation of simulants to CWAs for standoff detection [6-8]. Recently, improved methods have been developed to correlate simulants based on detector performance [9, 10]. Individual protection (suits and masks), collective protection (tents, vehicles, and buildings), and decontamination technologies will benefit from improved simulant selection based on relevant properties [11]. Finally, the chemical biological defense material development program should use a validated traceable simulant selection method [12].

A previously developed simulant selection process determined the important physical properties necessary to adequately challenge a defense technology. Then these parameters and others describing human, programmatic, and environmental concerns were weighted according to their importance [13, 14]. This approach can be used for any CWA defense technology if the relevant properties are considered. Examples of important physical properties for a technology are: the infrared (IR) spectrum for passive IR detection at a distance, mass fragmentation for a mass spectrometer, or reaction rate for decontamination. Use considerations were human (e.g., toxicity), programmatic (e.g., cost, availability), and environmental concerns (e.g., environmental permits). This process focused on using available database information and required estimation of physical property data when the database information was in question.

The simulant selection process initially considered protective performance of generic barrier materials that could be either semi-permeable or impermeable. To simulate the protective performance of barrier material against agent, the relevant physical properties considered were vapor pressure, surface tension, heat of vaporization, dipole moment, and viscosity. These parameters were weighted depending on use and

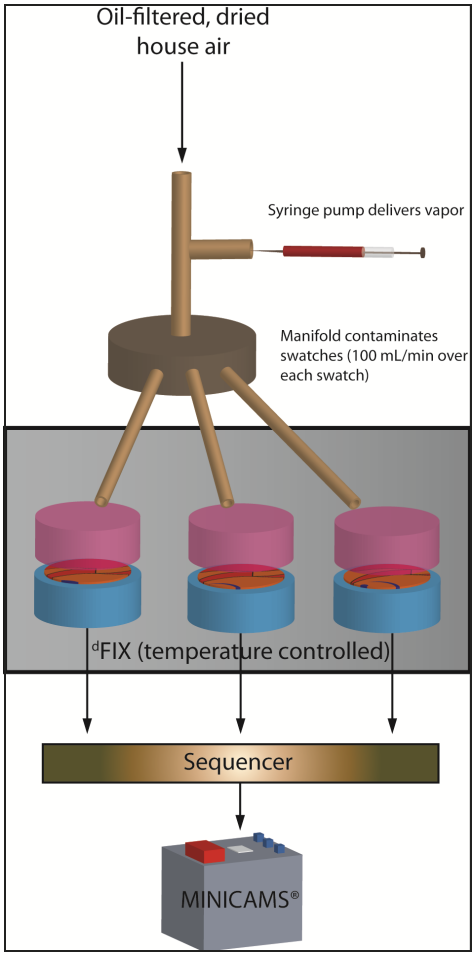

Figure 1. Vapor Permeation Test Fixture. Humid chemical vapor challenges were generated by the syringe and LC pumps and flowed over the top of the material in the cup. Sampling was done through a sequencer and MINICAMS®
(a miniature, automatic, continuous air-monitoring system) by sweeping the bottom of the cup with dry air. The dFIX provided temperature control.

physical values obtained by querying standard databases. Use considerations were human, programmatic, and environmental. The initial selection process searches yielded hundreds of potential chemical simulants. These searches were refined with more restrictive property searches and screening criteria, to reduce the number of chemicals to approximately 25.

The selection process generated quantitative ranking of simulants for HD [bis(2-chloroethyl) sulfide, Chemical Abstract Service (CAS) number 505-60-2], GB (isopropyl methylphosphonofluoridate, CAS number 107-44-8), and GD (pinacolyl methylphosphonofluoridate, CAS number 96-64-0). The best simulants based on defense technology, database values, and user needs were selected. After the selection process was developed and simulants were selected, process accuracy was determined with validation testing [13, 14].

The simulants were originally ranked for any generic barrier material, either liquid or vapor contamination and independent of the permeation test method. This general ranking was refined to select a simulant specifically for vapor challenge of an impermeable material, like the nitrile reference material used in this validation test. This test did not include a liquid challenge; therefore liquid challenge was excluded from the refined ranking. The refined scoring ignored less relevant physical properties such as surface tension, and focused on properties such as dipole moment and heat of vaporization. Refinement changed the simulant rank/order from the original ranking. This was expected since the original ranking did not consider the specifics of a swatch test.

To validate the process, a selection of ranked simulants were chosen as representatives of good, intermediate, and (when possible) poor matches to the agent. For HD, the best match predicted was MeS (CAS number 119-36-8), the intermediate match was triethyl phosphate (TEP, CAS number 78-40-0), and a poor match was phenyl acetate (PA, CAS number 122-79-2). Simulants 3-hepten-2-one (HP, CAS number 1119-44-4) and trimethyl phosphate (TMP, CAS number 521-56-1) were predicted as the good and intermediate matches for GB respectively. For GD, 4-chlorobutyl acetate (CA, CAS number 6962-92-1), TEP, and diisopropyl fluorophosphate (DFP, CAS number 866-23-9) were predicted to be the good, intermediate, and poor matches respectively. Previous testing quantified the breakthrough of agent and simulant vapor after a liquid challenge and derived values of the diffusion coefficient [15].

This article focuses on validation testing and the accuracy of the selection model by comparing the predicted rank/order of a simulant/agent match with a laboratory measured rank/order. The experimental test fixture and procedures will be described, as will the environmental controls and monitoring equipment. A theoretical approach for analysis of permeation data will be discussed by comparing measured experimental results with modeled results. Results of the time-dependent permeation modeling results, performance envelope equations, diffusion coefficients, activation energies, and ranking will be discussed and analyzed. Finally, the validation accuracy and value of the results will be described in the conclusion section.

Experimental

Materials

The experimental permeation test fixture configuration is capable of collecting time-resolved permeation concentration data at concentrations ranging from 0.03 to 100 mg/m^3. Subsequent to the work reported here, fixture improvements have reduced the lower detectable concentration limit. The test fixture design provides vapor challenges, effluent concentration measurements, rapid changes of relative humidity (RH), and environmental controls. The endpoint test configuration provided a fixture with environmental control that would fit inside a standard fume hood. The test methods were developed under this work and produced data compatible with a standard American Society for Testing and Materials (ASTM) method [16].

The Dugway Fixture (^{d}FIX) (Figure 1) was built around a small thermoelectrically temperature-controlled, thermally insulated Lexan® chamber. A mass flow controller regulated the flow of dried and oil-filtered laboratory air. A vapor challenge was produced by adding liquid simulant or agent through a heated tee, where it evaporated. Deionized water was also fed at a controlled rate through a liquid chromatography (LC) pump and evaporated into the air stream. The challenge was thoroughly mixed in a mixing chamber, and then split

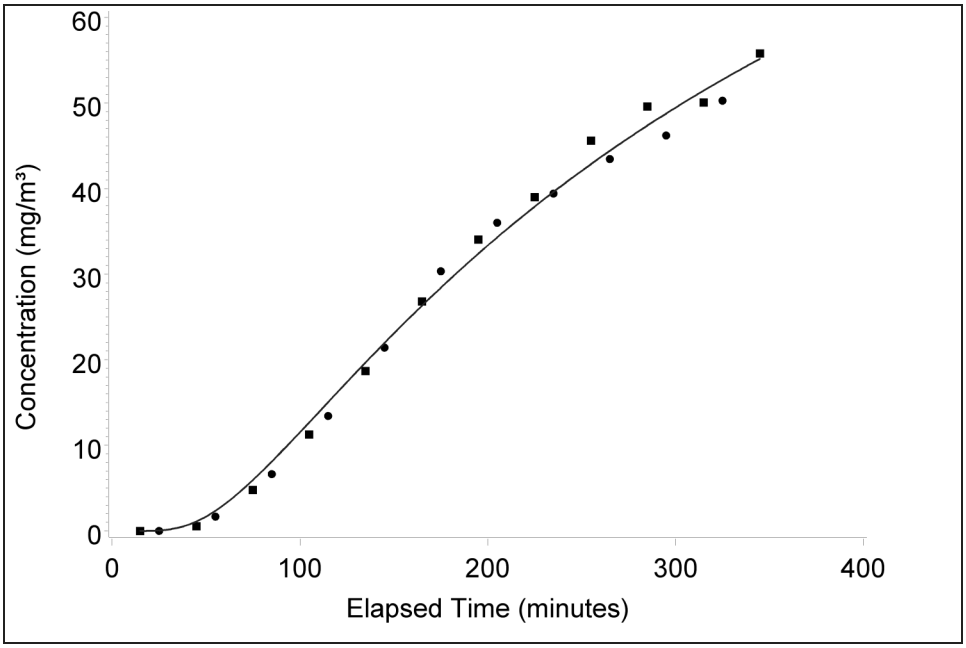

Figure 2. Fit of permeation data from two cups (closed and open circles) using Equation 1 (solid line) to determine the steady state permeation value (A) and diffusion coefficient (D).

equally among three standard military swatch permeation cells mounted in the [d]FIX. The temperature gradient of the [d]FIX has been shown to be within ±1°C across the chamber. The temperature can be reduced to 0°C or increased to 55°C in very short time periods (within an hour for most temperatures and four hours for extreme temperatures).

The permeation cells were the standard military swatch cups that can be disassembled, decontaminated and reused. The Aerosol Vapor Liquid Assessment Group (AVLAG) used these permeation cells for testing swatches of material [17]. The swatch cup design provided airflow above and below the 5.1-cm (2.1 -in) diameter swatch material. O-rings secured by a bolt-and-nut assembly sealed the perimeter of the swatch. The referee system showed less than 1 percent carry-over when switching between permeation cups. The current system ran for four months with no failures. Earlier tests were performed using nitrile rubber cut from the palm of a Kimberly-Clark® (Irving, Texas) purple nitrile powder-free medical examination glove (product number 55083). The nominal thickness was 0.15 mm (0.006 in).

Vapor that permeated the swatch was entrained by a flow of clean air to a sequencer valve (model number E16CMS) from Chemical Monitoring Systems (CMS) (CMS Research Corporation, Pelham, Alabama). The valve directed the 0.5 L/min sample flow from each cup to a gas chromatograph (GC) [MINICAMS® (a miniature, automatic, continuous air-monitoring system)] from CMS. The MINICAMS® was fitted with a flame ionization detector (FID) that measured concentration every 5 minutes (every 15 minutes for each of the three cups).

All agents (GB, GD, and HD) were obtained from the Edgewood Chemical and Biological Center, Maryland. Agent purity was greater than 95 percent as determined by Fourier Transform Nuclear Magnetic Resonance (FT-NMR) analysis. The simulants MeS, TEP, and CA were purchased from Fisher Scientific (Hampton, New Hampshire). The simulants PA and HP were purchased from Alfa-Aesar (Ward Hall, Massachusetts). The simulant DFP was purchased from Sigma Aldrich (St. Louis, Missouri). All simulants were used as received from the vendor and were at least 97 percent pure. The reference material used for characterization and subsequent GB and GD validation testing was a nitrile material deposited on a nylon mesh substrate. Reference material was cut from a sheet of nitrile rubber (product number SS-.017X36-34000, AAA-Acme Rubber Company, Tempe, Arizona).

Methods

Theory

The core component that affects every aspect of this effort is the fit of a physically meaningful permeation equation to the previously collected data. Information extracted from this fit will provide the fundamental values for comparison between process and measured correlation results. Additionally, the information will contribute to the design of future performance envelope test methods and provide values necessary for computational modeling. The literature permeation equation used is Equation 1 [18]. An example of how well Equation 1 fits permeation data is shown in Figure 2. Typically, fits have a correlation r^2 of 0.993.

A physics-based treatment of swatch permeation assumed that diffusion of vapor through swatch followed Fick's first and second diffusion laws. It was also assumed that the swatch was homogeneous, and that the value of diffusion coefficient (*D*) was independent of agent concentration. The model uses the "free diffusion" assumption, which states that diffusion occurs through a previously vacant semi-infinite slab [19]. Implicit in this model is the assumption that agent diffused more quickly through the boundary layer on each side of the swatch than through the swatch material itself. These assumptions involve a certain degree of approximation; however, it was expected that the resulting model would describe the material performance in a satisfactory manner. The diffusion equation was solved for one-dimensional diffusion at short times (Equations 1 and 2):

$$C(t) = A\ erfc\left(\frac{h}{\sqrt{4Dt}}\right)$$

(Equation 1)

Where:

C(t) = the permeated concentration

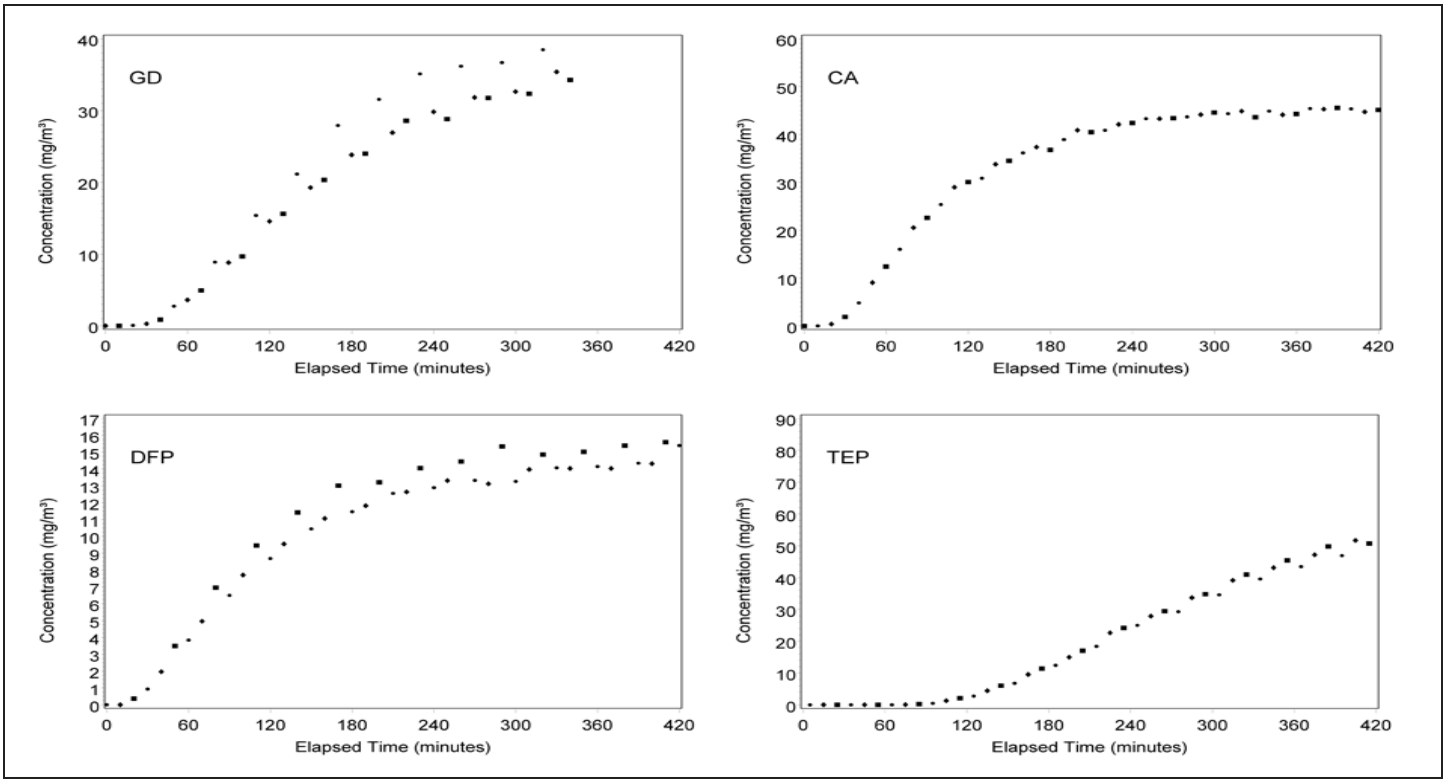

Figure 3. Example permeation curves through nitrile reference material at a challenge concentration of 200 mg/m3 and 35°C for soman (GD) and its simulants 4-chlorobutyl acetate (CA), diisopropyl fluorophosphate (DFP) and triethyl phosphate (TEP).

measured in mg/m^3.
A = the steady state concentration (mg/m^3) related to the challenge concentration and to the sweep flow rate below the swatch.
h = the swatch thickness (cm).
D = the diffusion coefficient (cm^2/s).
t = the time since the start of the test (s).

$$erfc(x) \equiv \frac{2}{\sqrt{\pi}} \int_{x}^{\infty} e^{-u^2} du$$

(Equation 2)

Where:
erfc(x) = the complementary error function.
x = independent variable.
u = variable of integration.

A detailed theoretical analysis suggested that Equation 1 was valid for a short time ($t < h^2/4D$); however, in practice, Equation 1 fit the data well over longer times. The quality of the fit suggests that the approximations made during the modeling process were sufficiently modest to yield a realistic model.

Experimental Design

Experimental design was used to determine the minimum number of trials and conditions necessary to determine the coefficients *A* and *D*. Experimental design offers considerable reduction in cost and schedule compared to the method of varying one parameter at a time. Typical D-optimal designs assume that permeation rate has a polynomial dependence on each continuous variable (challenge concentration, temperature, and RH) across the range of conditions considered in the experiment [18].

One hundred thirty five (135) sets of conditions (agent or simulant, challenge concentration, temperature, and humidity) were chosen for comparison. The method of comparison required integration of the permeation curves. In the chemical defense community, the integrated concentration *I* is referred to as concentration-time (Ct).

$$I = \int_{0}^{t85\%} C(u)du$$

(Equation 3)

Where:
I = the integrated concentration (mg-minutes/m^3).
t85% = the time when the trial was terminated.
C(u) = the concentration at time u (mg/m^3).
u = the variable of integration (minutes).

The parameter *I* is important for chemical defense as it can be related to the total amount of agent vapor that would be inhaled by a warfighter inside the protective equipment. Permeation experiments were terminated at a time *t85%* when it was estimated that the concentration had reached 85 percent of its steady state value. Therefore, the concentration is integrated from start of trial (time 0) to *t85%*. Concentrations were integrated at each set of conditions for each agent and its corresponding simulant. The complete comparison between agent and simulant was rep-

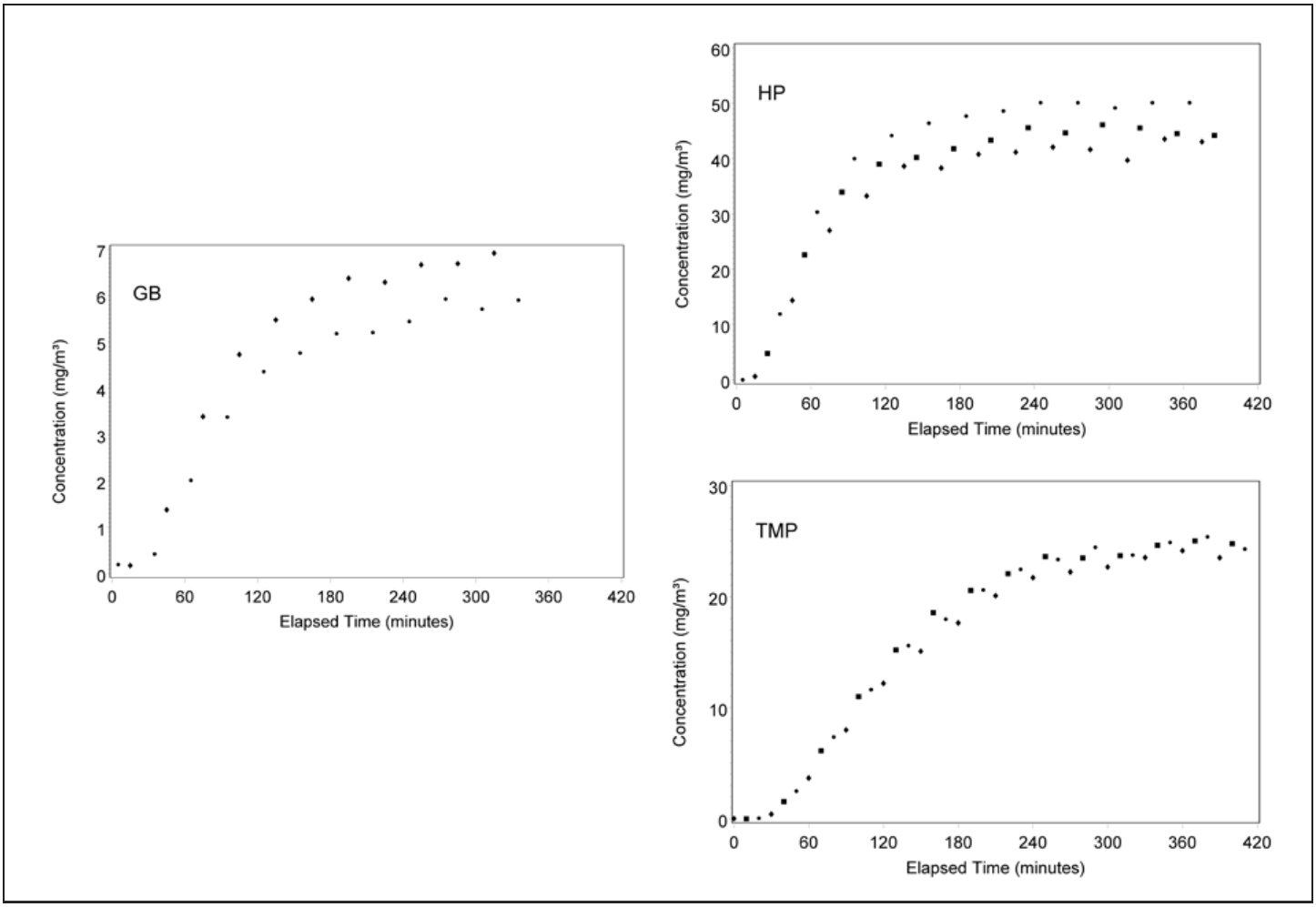

Figure 4. Example permeation curves through nitrile reference material at a challenge concentration of 200 mg/m3 and 35°C for Sarin (GB) and its simulants 3-hepten-2-one (HP) and trimethyl phosphate (TMP).

resented by the average over 135 sets of conditions (Equation 4). The agent simulant relationship can be expressed as the ratio between performance with agent and performance with simulant.

$$Comp = 100\% \times \frac{\sum_{1}^{135} V_j}{135}$$

(Equation 4)

Where:
Comp = the average comparison ratio of agent to simulant over 135 trials.
V = the normalized agent/simulant performance value.
j = the trial number.

Using the values of *I*, a "reduced mass" calculation was used to determine how closely the simulant value matched the agent. For a perfect match, the value in Equation 5 would be 100 percent. The final comparison of the measured rank/order results were compared with the simulant selection process.

$$V = \left| \frac{2I_{simulant}}{I_{simulant} + I_{agent}} \right|$$

(Equation 5)

Where:
V= the normalized agent/simulant performance value.
$I_{simulant}$ = the integrated concentration for simulant.
I_{agent} = the integrated concentration for agent.

Results and Discussion

Permeation results were collected for ten compounds at three temperatures (35, 45, and 55°C), three challenge concentrations (50, 125, and 200 mg/m^3) and three water vapor concentrations (0, 10, and 20 g/m^3). Examples of typical permeation results are given in Figures 3 through 5 for tests conducted at 200 mg/m^3 and 25°C. The plots are typically for two to three cups run simultaneously, which show remarkably low cup-to-cup variability. As the plots show, the permeation curve from each cup overlaps well with the other cups in the tests. The exceptions were the HD, MeS, and PA trials (Figure 5) where a simple test material was used (nitrile gloves with varying thicknesses). The cup-to-cup variability rose from less than ±1 percent to well over ±10 percent when testing gloves were used instead of reference material.

The curves in Figures 3 through 5 are grouped to place agent performance curves with the simulant performance curves. For example, Figures 3 shows GD, TEP, CA, and DFP

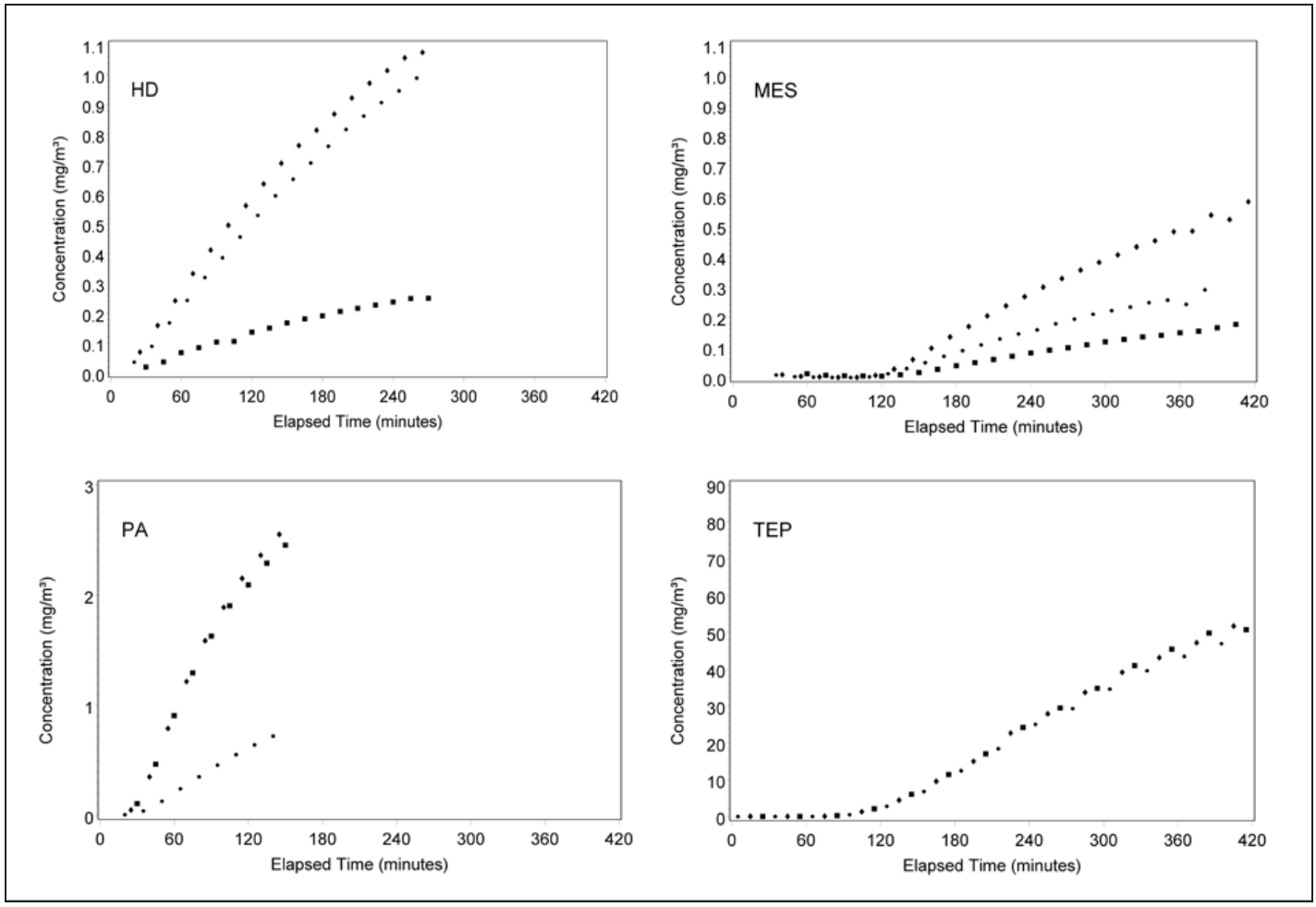

Figure 5. Example permeation curves through glove material at a challenge concentration of 200 mg/m3 and 35°C for distilled mustard (HD) and its simulants triethyl phosphate (TEP), phenyl acetate (PA), and methyl salicylate (MeS).

data. Visual inspection would indicate that CA would be the best match for GD. Similarly, GB (Figure 4) is best matched by TMP and not HP. Inspection of the nitrile glove plots would also correctly assign MeS (Figure 5) as the best simulant for HD instead of PA which permeated rapidly.

All permeation curves were collected following the experimental design, and fit using nonlinear least squares fitting to the permeation equation given by Equation 1. The r^2 value for each fit ranged from 0.904 to 0.999 with the average being 0.993. Diffusion parameters and steady state values for all environmental conditions are given in Tables 1 and 2. Two tested compounds, DFP and PA, were excluded from Tables 1 and 2 because DFP underwent a chemical reaction on the surface of the nitrile that stopped permeation, and the rapid permeation of PA swiftly exceeded the detector's operational range. Thus, PA and DFP could not be correlated over the temporal range of the test.

Information extracted from Tables 1 and 2 using the experimental design yielded a better understanding of how the environment affects permeation. Based on the information in Tables 1 and 2, temperature and challenge concentration had the most effect on permeation rate while RH had little effect on permeation. This result is important because most permeation test designs in materials science are set up for RH and may over emphasize the significance of RH.

The following comparison can be made between the reference material and glove results for TEP. The glove data (Table 2) were over an order of magnitude different for the same thickness. Potential reasons for this difference include formulation and production methods (dipped coated versus deposition onto a nylon mesh support). The cup-to-cup variability increased by a factor greater than five as noted above. Again, the glove material validated the process using real world items as well as pristine reference material.

NOTE: Any correlation between agents and simulants must be made on the specific material of interest. A general agent-simulant correlation based on material class may be incorrect.

The *A* and *D* parameter values were fitted as a function of temperature and challenge concentration, using least-squares fitting. The steady state permeation concentration *A* was not understood historically, but is critical for protective acquisition programs to estimate threat, dosage, and countermeasures. In addition, understanding steady state values

Table 1. Test results and conditions for the reference material.

Compound	Temp. (°C)	Conc. (mg/m³)	AbsH[a] (g/m³)	RH (%)	A[i] (mg/m³)	D[ii] (cm²/s)
TEP	35	50	8.9	22.5	33.1	2.31E-09
	35	50	10.5	26.6	42.7	1.93E-09
	35	50	20.3	51.4	20.1	1.49E-09
	35	50	22.0	55.6	11.7	7.07E-09
	35	125	0	0	16.3	4.25E-09
	35	200	12.3	29.9	181.5	2.77E-09
	45	200	18	27.5	150.8	3.10E-09
	50	45	0	0	36.2	5.27E-09
	50	45	0	0	25.1	8.19E-09
	50	55	0	0	24.1	5.82E-09
	55	50	0	0	38.2	8.47E-09
	55	200	0	0	250.0	1.00E-08
	55	200	9	8.5	112.8	1.00E-08
TMP	35	50	0	0	12.3	8.89E-09
	35	50	0	0	11.5	1.23E-08
	35	50	0	0	29.2	5.60E-09
	35	200	0	0	61.7	4.54E-09
	35	200	17.7	43.3	48.3	9.67E-09
	45	125	11.5	17.6	86.0	2.98E-09
	55	50	0	0	10.2	3.24E-08
	55	50	16.7	16	7.4	5.13E-08
	55	200	0	0	40.3	3.29E-08
	55	200	18.9	16.5	16.9	2.67E-08
HP	35	50	9	22.8	7.2	3.46E-08
	35	200	0	0	63.2	5.91E-08
	35	200	0	0	120.2	2.09E-08
	35	200	9.8	24.7	68.1	2.94E-08
	35	200	23.3	59	16.0	5.06E-08
	45	200	14.4	22	88.1	2.10E-08
	55	50	0	0	8.2	5.34E-08
	55	50	0	0	7.3	8.31E-08
	55	50	20.3	19.5	2.7	4.62E-08
	55	200	13	12.5	37.5	7.50E-08
CA	35	50	0	0	17.0	8.67E-09
	35	50	0	0	14.5	9.79E-09
	35	50	0	0	15.1	1.22E-08
	35	50	13	33	13.1	1.53E-08
	35	200	9	22.8	65.2	2.05E-08
	35	200	17.2	43.4	75.7	1.26E-08
	45	125	14.2	21.7	40.8	2.13E-08
	45	125	17.3	26.4	28.4	3.85E-08
	45	200	0	0	77.6	1.54E-08
	55	50	0	0	8.5	5.89E-08
	55	50	9	8.5	11.8	1.89E-08
	55	50	18.2	17.5	8.7	4.36E-08
	55	200	12.9	12.4	53.6	4.30E-08
GB	35	50	18.5	46.9	5.1	5.00E-09
	35	125	8.2	20.7	6.2	1.26E-
	35	200	0	0	11.3	1.53E-08
	55	50	0	0	2.7	5.49E-08
	55	200	0	0	8.9	2.20E-08
	55	200	17.6	17.0	7.5	4.84E-
GD	35	50	0	0	21.0	5.74E-09
	35	125	9.4	23.8	55.7	5.67E-09
	35	200	0	0	169.3	4.23E-09
	35	200	15.5	39.3	91.0	6.28E-09
	55	50	15.1	14.5	9.0	3.27E-08
	55	200	0	0	63.3	2.11E-08

[a]Water vapor content

will reduce test costs by eliminating unnecessary future testing and guiding statistical test design. Testing showed *A* did not depend on RH or temperature for any of the chemicals. All chemicals had an increase in the values of *A* at 200 versus 50 mg/m^3 challenge concentration C_0, as expected but *A* was not exactly proportional to C_0. The lack of simple proportionality probably arose from approximations and experimental uncertainties. The equation for calculated steady state concentration values is given by a linear Equation 6 (as expected for increasing concentration). The coefficient values are given in Table 3.

$$A = Coef_0 + Coef_1 C_0$$

(Equation 6)

Where:
A = the steady state concentration.
$Coef_0$ = the minimum value of *A*.
$Coef_1$ = the dependence of *A* on challenge concentration.
C_0 = challenge concentration.

Table 2. Test results and conditions for Nitrile Glove material.

Compound	Temp. (°C)	Conc. (mg/m^3)	AbsH[a] (g/m^3)	RH (%)	*A* (mg/m^3)	*D* (cm^2/s)
TEP	35	50	0	0	3.6	2.92E-10
	35	50	10	25	3.5	3.25E-10
	35	200	0	0	2.2	4.40E-10
	35	200	10	25	4.3	6.02E-10
	55	50	0	0	0.5	1.57E-09
	55	200	10	10	4.2	1.13E-09
MeS	35	50	0	0	1.6	2.84E-09
	35	50	10	25	0.5	5.01E-09
	35	200	0	0	1.2	2.89E-09
	35	200	10	25	1.5	3.76E-09
	35	200	10	25	0.9	4.27E-09
	55	50	10	10	0.7	3.07E-08
	55	200	0	0	0.9	2.21E-08
HD	35	50	10	25	0.3	3.35E-09
	35	50	10	25	0.4	2.91E-09
	35	200	0	0	2.4	8.29E-09
	35	200	0	0	1.8	8.39E-09
	45	50	0	0	1.2	5.53E-09
	45	50	0	0	1.0	6.85E-09
	45	200	10	15	2.5	9.64E-09
	45	200	10	15	5.0	6.37E-09
	55	50	0	0	0.4	1.36E-08
	55	50	0	0	2.7	1.87E-08
	55	200	0	0	4.7	1.98E-08
	55	200	0	0	0.8	9.50E-09

[a]Water vapor content

Determining the diffusion coefficient *D* through a material is a standard measurement that determines the temporal profile of the permeation curve. As with *A*, understanding the experimental factor for determining *D* will optimize future testing by quantifying the effect of environmental conditions, and focus efforts on the parameters that matter most. Diffusion coefficients for the reference nitrile only depended on temperature, and not the challenge concentration or RH. For gloves, temperature was the dominant contributor, but a weak dependence was observed for RH. No dependence was observed for challenge concentration. The strong dependence on temperature was expected, and the relationship can be used to calculate permeation activation energies.

Values of *D* were fitted to Equation 7; coefficients are given in Table 4:

$$ln(D) = Coef_2 + Coef_3/T + Coef_4 \times RH \quad \text{(Equation 7)}$$

Where:

ln(D) = is the natural log of the diffusion coefficient.

D = the diffusion coefficient in cm^2/s.

T = the temperature in K.

$Coef_2$ = limiting value of *ln(D)* for 0% RH and *T* approaching infinity.

$Coef_3$ = the dependence of *ln(D)* on temperature that is related to activation energy.

$Coef_4$ = the dependence of *ln(D)* on RH.

RH = the relative humidity in percent.

Using Equation 7, the parameter *D* is predicted to within an average of approximately 25 percent for the glove material, and 65 percent for the reference material. Random errors were expected to be present in glove thickness because of manufacturing variations. Because the concentration that permeated depended on (*h*/*ÖD*), the error is quadratic in *h*. A thickness error of 5 percent would translate into an error of about 10 percent in the value derived for *D*. Similar thickness errors in the reference material were not observed, but sheet production may be a concern in trial-to-trial variability. Determination of the diffusion coefficient provided the data necessary to calculate HD, GB, and GD diffusion activation energies that were estimated at 16, 12±2 and 23±3 kilocalories per mole (kcal/mol), respectively. Table 5 compares the values of each compound as a simulant for the corresponding agent using three different quantities: the global prediction, the specific prediction, and the measured value. Each quantity is discussed below.

The performance-envelope equations employed to predict values of *A* and *D* were used over a wide range of conditions to compare agent-to-simulant performance over the same range. As described above, 135 sets of conditions were selected over the testing envelope. Integrated concentrations of the permeation curve at 85 percent of the steady state concentration were used for comparison. The concentration-times were only used here to calculate agent-simulant performance by using a normalized ratio of agent concentration-time to simulant (Equation 5). The resulting measurements were averaged over 135 sets of conditions, and then compared with predicted values from the selection process (Equation 4, Table 5). The predicted values were the sum of weighted performance values of properties for agent and simulant (Equation 5) [13]. A simulant that matched an agent perfectly would score 100 percent.

The predicted results in Table 5 show two sets of data: the global prediction made for any material, challenge method, and laboratory permeation test and the specific prediction refined for impermeable material with vapor challenge testing. The measured values are also scored where 100 percent is a perfect match. Magnitudes of the predicted values over the measured performance envelope are not directly comparable to the predicted values. The reason for the lack of comparability is because the predicted values used a weighting scheme where measured results were derived from laboratory experiments. The inability to compare magnitudes between predicted and measured values requires the use of rank/order for assessing accuracy.

These values were reduced to rankings as follows. If the score for

Table 3. The coefficients for Equation 6 to calculate the Steady State Concentration, A.

Material	Compound	$Coef_0$[a] (mg/m^3)	$Coef_1$[b]
Reference	CA	-6.27	0.365
	GB	2.015	0.036
	GD	-17.29	0.622
	HP	-13.17	0.393
	TEP	-21.63	0.927
	TMP	9.70	0.193
Glove	HD	-0.34	0.026
	MES	0.84	0.001
	TEP	2.21	0.007

[a]$Coef_0$ – mg/m^3 from Equation 6, the minimum value of *A* in Equation 6.
[b]$Coef_1$ – the dependence of *A* on challenge concentration in Equation 6.

Table 4. The coefficients for Equation 7 to calculate the diffusion coefficient,

Material	Compound	$Coef_2$[a]	$Coef_3$[b] (K)	$Coef_4$[c] ($\%RH^{-1}$)
Reference	CA	0.154043	-2403.16	0
	GB	4.337241	-2996.13	0
	GD	7.029078	-3434.42	0
	HP	-8.49935	-1118.72	0
	TEP	-0.88115	-2469.75	0
	TMP	5.267163	-3172.75	0
Glove	HD	-3.0271	-1582.96	-0.01121
	MES	5.8090	-4407.44	0.00665
	TEP	-0.5983	-2712.42	0.00225

[a]$Coef_2$ – limiting value of the natural log of diffusivity for 0 percent RH and temperature approaching infinity in Equation 7.
[b]$Coef_3$, – dependence of *D* on temperature in Equation 7.
[c]$Coef_4$, – dependence of *D* on humidity in Equation 7.

Table 5. Simulant Quality Percent Score.

Agent	Simulant	Global Prediction (%)	Specific Prediction (%)	Measured for Standard Material[a] (%)	Measured for Glove[a] (%)
GD	CA	81	98	98	NA
	TEP	69	86.5	80	NA
	DFP	67	74	React	NA
HD	MeS	89	95	NA	70
	TEP	86	91	NA	4
	PA	63	74	NA	Off scale
GB	HP	90	89.5	26	NA
	TMP	75	93	38	NA

[a]Magnitudes of the measured results are not comparable to predicted results; NA – Not Applicable

two simulants differed by less than 3 percent, the two simulants were ranked equally for that agent. Rank/order results derived from Table 5 are given in Table 6. For the global prediction, the predicted rank/order matched the observed rankings only 63 percent because the original ranking was determined for any type of challenge on all materials with no laboratory permeation specificity. When the selection process was refined to look at properties and weightings that affected permeation through an impermeable material by a vapor challenge, the observed ranking matched the predicted rankings in 100 percent of the cases. The selection process was adequate for broad and excellent for specific requirements with all selected simulants that were correlatable to the agent except the poorest of matches (PA and DFP).

Conclusions

The use of surrogates to replace dangerous material in the military has a long history; however, military use of surrogate chemicals (simulants) in place of toxic chemicals is rather recent. Simulants provide a safe and less expensive way to test chemical warfare equipment, and have become increasingly important due to regulatory, safety, and environmental considerations (e.g., prohibition on open air agent releases). Concerns exist regarding the use of legacy simulants because of limited traceability of simulant selection and correlation documentation. Well-chosen simulants and a validated correlation should produce good performance assessments of chemical warfare equipment for personnel protection.

Concerns regarding simulant selection arose during a prior program to develop a simulant selection process based on relevant physical properties and user requirements, such as safety. A process was developed and implemented to select simulants for permeation and collective protection materials (e.g., tents) testing. The selection process ran multiple times with increasingly restrictive criteria to reduce hundreds of potential simulants to 25. The results provided weighted scores for HD, GD, and GB simulants. Once a rank/order list of simulants was generated, the best, intermediate, and poor scoring simulants were selected for each agent to validate the process. MeS, TEP, and PA simulants were selected to assess permeation relative to HD. CA, TEP, and DFP simulants were selected assess permeation relative to GD. GB permeation simulants included HP and TMP. The suitability of the selection process was determined by comparing the predicted order of permeation rates with the laboratory measured order of permeation rates.

Laboratory testing measured agent and simulant vapor permeation

Table 6. Rank/order comparison demonstrating the accuracy of the simulant selection process.

Compound	Global Prediction	Specific Prediction	Measured Results
HD	MeS > TEP > PA	MeS > TEP > PA	MeS > TEP > PA
GB[e]	HP > TMP	TMP > HP	TMP > HP
GD[h]	CA > TEP = DFP	CA > TEP > DFP	CA > TEP > DFP

through standard nitrile material and nitrile gloves. Experiments used a new hood-size temperature controlled fixture ([d]FIX) that controlled temperatures ranging from 0 to 55°C with less than 1°C variability. Vapor challenges used a LC pump (RH) and a syringe pump (agent/simulant) generation system to produce agent/simulant vapor challenges and RH, respectively. Permeation monitoring used a sequencer and miniature GC instrument to simultaneously monitor three permeation test cups that provided permeation curves with very little difference between cups. Concentration, RH and temperature were used to map the permeation performance. Each of the resulting data curves was fit to a standard permeation equation to determine the diffusion coefficient and steady state concentration. Fits had an average r^2 of 0.993. ASRs illustrated how well the simulant corresponded to the agent over a wide range of concentrations, RHs, and temperatures (135 sets of conditions). Activation energies for permeation were derived from the dependence of *D* on temperature (Table 4 and Equation 7).

The primary goal of validating the simulant selection process was achieved. The validation process demonstrated that the process adequately selected simulants for a broad range of permeation tests, which improved when specific tests were considered. Adequacy was determined by comparing the global (unknown material, challenge, and permeation test method) predicted simulant rank/order to the measured order. Adequacy improved by comparing the specific (impermeable material in a vapor challenge) predicted simulant rank/order to the measured order. Rank/order values for the predicted global simulant rank/order matched the measured order by 63 percent and the predicted specific order matched the measured 100 percent of the time. Based on the rank/order comparison, the validation of the selection process for protective equipment is accurate enough to be used for acquisition program simulant selection that will test fielded equipment to be used by soldiers and potentially used by first responders. Conclusions from this validation study resulted in the development of a sound test procedure, data analysis method, and testing fixture.

The dependence of the permeation rate upon experimental variables discovered in simulant selection will be applied during acquisition testing. This information should facilitate the planning of acquisition testing to reduce the number of trials or select the trials of most importance while more accurately determining values of physical properties (e.g., diffusivity).

Future efforts will focus on repeating these experiments and results in another laboratory, as well as applying the simulant selection process to another technology. Permeation through other materials will be assessed. Offgassing from materials after a vapor exposure will be assessed with the breakthrough of vapors through filters. The data analysis, physical models, performance metrics, and agent-simulant relationships will be revised accordingly. This process must be repeated before it is standardized and its potential is known.

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Computed Image Backscatter Radiography: A Novel Method for Non-Destructive Examination

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University of Florida

Non-destructive examination techniques are playing an increasingly larger role in the border security of the United States (U.S). The need to quickly (and often discreetly) query containers, cargo and even personnel entering the U.S. for hidden contraband is a challenging engineering problem. Fundamentally, we would like to be able to "see" into suspicious containers without having to resort to opening them. Backscatter x-ray radiation, a key non-destructive examination technology, is currently being used at ports, border crossings, and in airport security, to do just that. As will be seen, the advantages of backscatter radiography are significant, including increased probability of detecting hidden contraband, improved scanning and output control, and the ability to unobtrusively query targets by controlling the penetration depth of the radiation.

This article outlines the basic science behind x-ray backscatter radiography and describes a new technique developed to improve acquisition time - Computed Image Backscatter Radiography (CIBR). This work was completed at the University of Florida as thesis research for a Master of Science degree in Nuclear Engineering enroute to the Department of Physics & Nuclear Engineering at the United States Military Academy. This work was originally inspired by the need to develop a fast target acquisition method to find improvised explosive devices (IED) however, it quickly evolved into the alternative scanning method presented here.

Backscatter radiography relies on x-rays Compton-scattered back towards a detector on the same side of the target as the radiation source. This positioning of both the source and detector on the same side of the target is the primary advantage of backscatter radiography. This method of positioning, coupled with the ability to reduce the visible angle of the detectors to the radiation (collimation), allows the user to select the depth to which they would like to examine, which, in turn, allows objects to be recognized that were previously hidden by high density materials or inaccessible due to the inability to place a detector behind the target.

At present, the primary disadvantage of x-ray backscatter radiography is acquisition time. The relatively small numbers of x-rays backscattered, compounded with the low efficiencies of the most common types of x-ray detectors, results in long acquisition times (depending on scan size, from minutes to days). Acquisition time can be adjusted based upon the image quality needed, the strength of the radiation source, and the size and number of detectors, but is ultimately limited by the maximum dose that can be applied to the target.

Most current methods of backscatter radiography use a rastering technique with a pencil beam source to gather data (Figure 1). As the pencil beam passes over each differential volume (or voxel) in the target of interest, the detectors gather data from that particular voxel. The beam moves in a continuous motion, rastering back and forth until the entire target area has been scanned. The atomic properties of the target determine the amount of backscatter. Differences in the absorption and scattering cross sections of the target create the contrast observed in the image captured by the detectors.

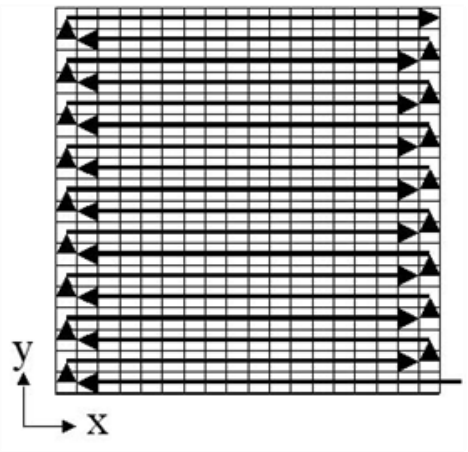


Figure 1. Typical Rastering Technique for Backscatter Radiography.

CIBR differs from conventional backscatter radiography in three significant ways: 1) it utilizes a fan beam x-ray source instead of a pencil beam; 2) it utilizes rotational motion instead of a rastering technique; and 3) it requires specialized image reconstruction techniques. CIBR is an innovation derived from the Radiography by Selective Detection (RSD) rastering backscatter radiography method patented by the Scatter X-Ray Imaging (SXI) group led by Dr. Edward Dugan at the University of Florida.

In CIBR, the fan beam source changes the data acquisition method, the strength required of the radiation source, and amount of backscattered radiation generated. The basic principles of backscatter radiography remain the same however. That is, differing absorption and scattering

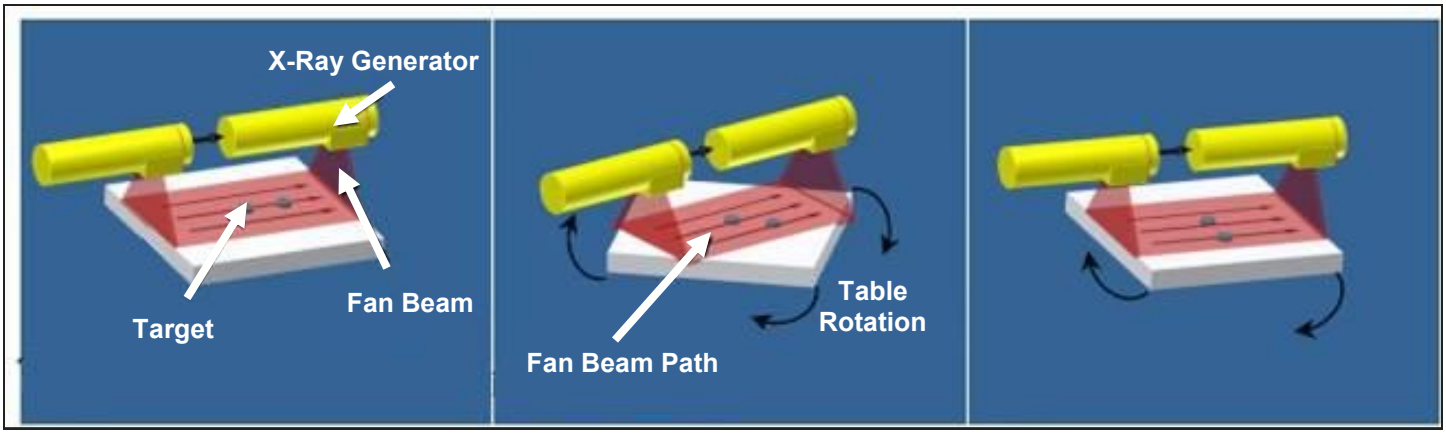


Figure 2. CIBR Rotational Collection Technique example. X-ray generator start and finish locations, along with fan beam and scanned area, are shown. Arrows on the target within the scanned area show the direction of the scan.

cross-sections are responsible for image contrast. However, instead of creating the image voxel by voxel, as done in conventional backscatter techniques, CIBR images are created directly from the scanned data, using advanced post-processing image reconstruction techniques.

The fan beam precludes data acquisition using rastering techniques, and instead requires rotational motion. In CIBR, the fan beam must be as wide as the target area of interest. The fan beam sweeps from one side to the other in a direct line. The target then is rotated in relation to the fan beam (or vice versa), and another sweep taken. This process continues in uniform increments through a 360° rotation. The size of the angle increments determines quality of the reconstructed image as well as acquisition time. An example of the CIBR rotational collection technique is shown in Figure 2. above.

The data acquisition method shown in Figure 2 is only one of several different possible techniques for CIBR. For example, the method of rotation can be changed, the x-ray source can be rotated instead of the target, or a rotating fan beam aperture can be used instead of rotating the entire generator or the target. Instead of moving the generator across the target for the scan, the generator can simply be pivoted, creating a sweep. The target itself could also be moved in relation to the generator. The possibilities are many and varied. Regardless of exact mechanical method of data acquisition, the basic principles of the scan and rotation remain the same.

Another advantage of a fan beam is that it uses orders of magnitude more photons than the typical pencil beam, resulting in increased scan speeds, shorter image acquisition times, and a reduction in power. This higher number of photons also results in a higher number of backscatter photons, leading to higher contrast. As an example, a 30.5 x 0.5 mm fan beam aperture is 15.25 times larger than a 1 mm square RSD pencil beam aperture. Since the number of photons incident on the target is proportional to aperture size, a larger source aperture leads to more backscatter photons. With an increase in the number of backscattered photons, the output of the x-ray generator may be lowered and the image scanning speed may be increased, if desired.

Currently, CIBR uses a filtered back-projection technique to reconstruct the image. Filtered back-projection was originally designed for use in tomography, most notably Computed Tomography (CT) systems, which use a similar rotational method of data acquisition for transmission images. Although this method of image reconstruction works for CIBR, it does not adequately account for all the CIBR data and degrades the image. Therefore, design of a CIBR-specific reconstruction technique is essential for CIBR to reach its full potential.

Fundamentally, CIBR requires a different type of image reconstruction technique than that used in conventional rastering backscatter radiography. Conventional image acquisition techniques gather the data in a voxel-by-voxel method, creating the image as the scan runs. The next voxel does not affect the previous voxel reconstruction. All that changes from voxel to voxel is the relative contrast. Using CIBR, however, the image cannot be reconstructed until the scan is complete as the reconstruction requires all the scan data. This reconstruction currently takes place almost instantaneously, but cannot be done until the scan is complete and all the data has been collected.

Theoretically, CIBR poses many advantages over the current backscatter systems with several orders of magnitude decrease in image acquisition time. To demonstrate this, a prototype CIBR machine was designed and built by the University of Florida's SXI group. This prototype, utilizing filtered back-projection image reconstruction, showed improvements in acquisition time of up to two orders of magnitude.

Initial tests were performed with a compact x-ray generator system and four Yttrium Oxyorthosilicate (YSO) scintillation detectors (Figure 3). The system scanned back and forth over a target placed below it on a rotating table.

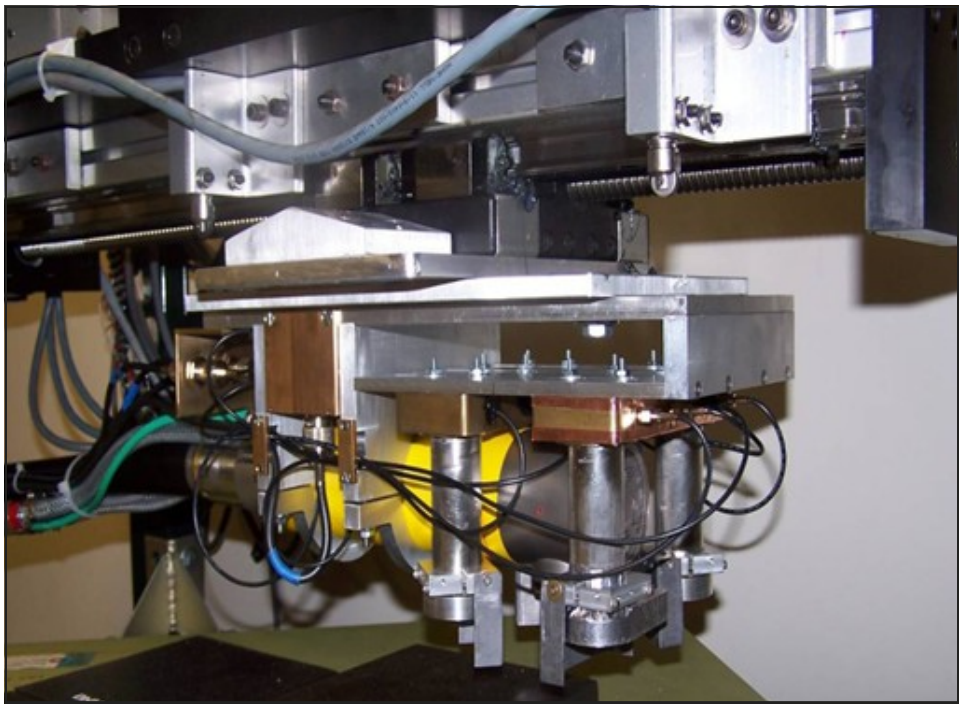


Figure 3. CIBR scanning system setup for proof of principle. This system consists of a compact x-ray generator and four scintillation detectors that move linearly over a rotating target table.

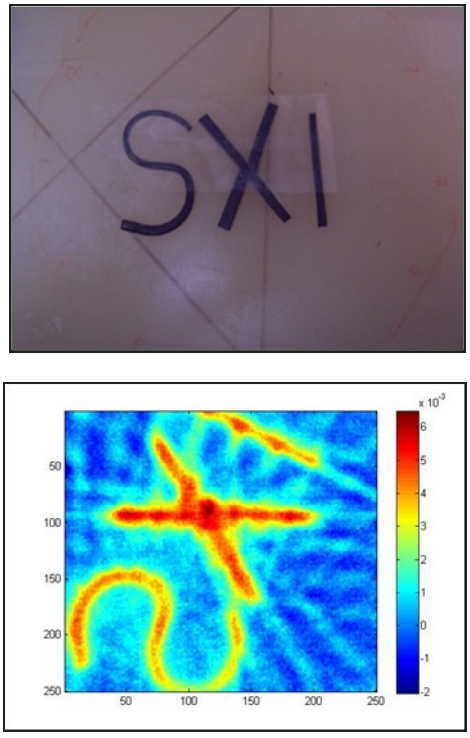


Figure 4. Lead "SXI" on nylon backing test object and its CIBR reconstructed Image.

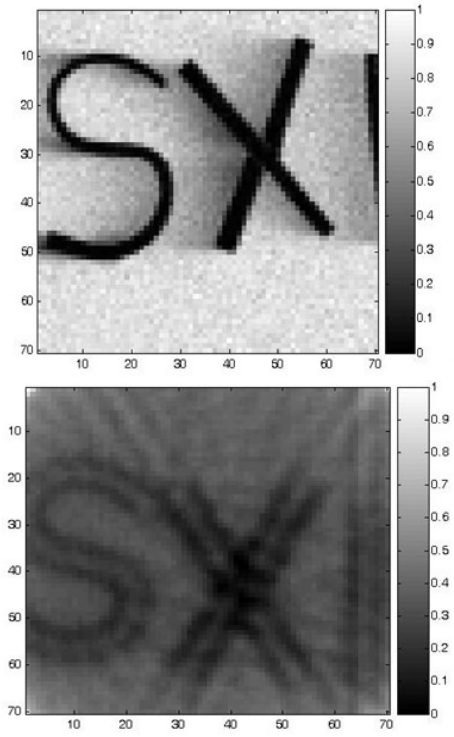


Figure 5. CIBR image compared with RSD Image. A) CIBR reconstructed image. B) RSD pencil beam image.

After initial success scanning simple geometries, the CIBR system was then tested on a more complex geometrical object- a lead "SXI" on a nylon backing. The target and the resulting scan images are shown in Figure 4.

As can be seen, the letters "SXI" are clearly visible and are easily discerned in the reconstructed image, demonstrating that the system can be used for complex geometries using the filtered back-projection reconstruction method. Note that the reconstructed image is a mirror image of the actual target. This is corrected by inverting the data before image reconstruction.

Figure 5 shows a CIBR reconstructed image compared to that of a traditional pencil beam RSD image. Although the RSD-generated image is clearer, these images show that CIBR can also take complex geometric scans of high contrast surface objects and resolve them to create recognizable images. With the development of CIBR-specific reconstruction methods, image quality will continue to improve until it is comparable with the RSD pencil beam scan quality. Even with current methods, however, CIBR can create images of reasonable quality.

CIBR is also able to shorten the acquisition time compared to RSD, but there are tradeoffs. RSD cannot scan at the low power that CIBR can because it cannot generate enough counts to produce an image. The RSD image in Figure 5 had to be created with a power setting an order of magnitude higher than that of the CIBR image. Using RSD, the count rate can be adjusted by either adjusting the pixel size, the dwell time per pixel, or by increasing the power (current and/or voltage) of the generator. However, even with the current at its maximum setting, the count rate for RSD is still so low that images are often difficult to create. If pixel size is to be kept the same, the dwell time must be longer. However, as seen in Table 1, when the acquisition times of RSD versus CIBR are compared, it is seen that CIBR offers significant promise for reducing the

Table 1. Comparison of image acquisition time for the images shown in Figure 5 based on a typically achievable CIBR count rate.

	Count Rate (counts/ sec)	**Time** (sec)	**Count Rate** (counts/ sec)	**Time** (sec)	**Count Rate** (counts/ sec)	**Time** (sec)
RSD	7000	545	200,000	15,570	650,000	50,605
CIBR	650,000	470	650,000	470	650,000	470
% Reduction in Time for CIBR		16%		3200%		10,650%

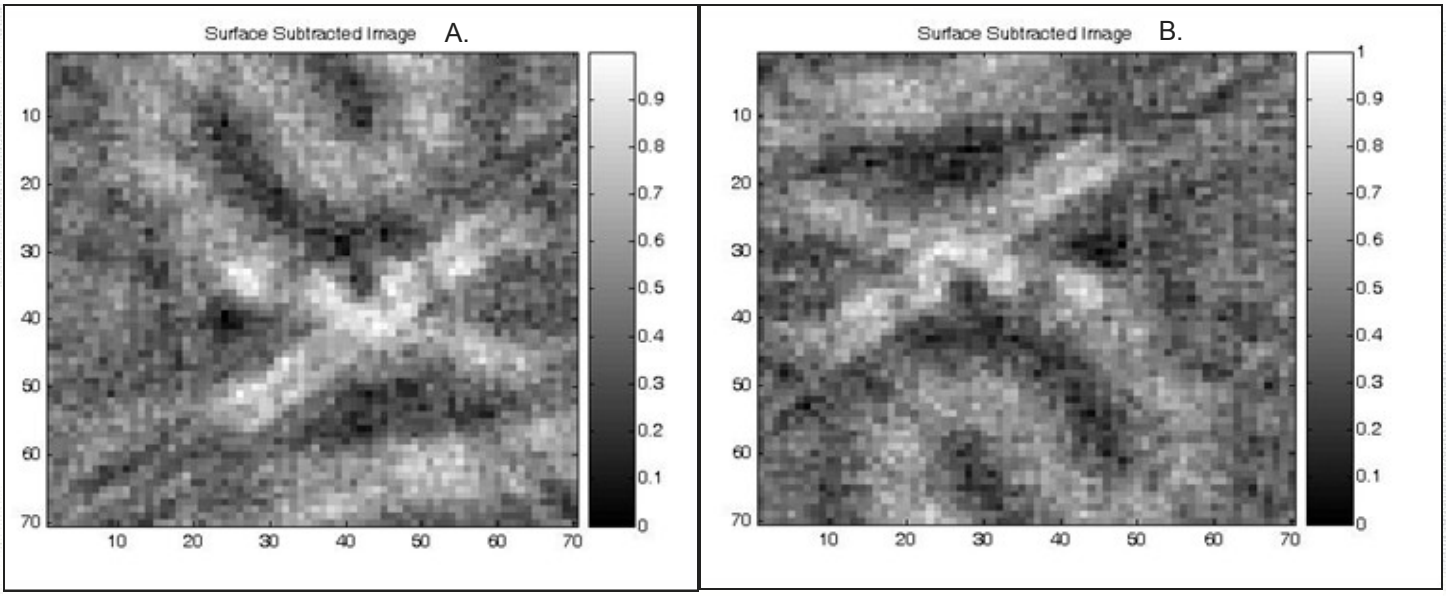


Figure 6. Subsurface CIBR scan images of lead "SXI" letters on nylon placed under varying amounts of foam. A. 3.5 cm of foam overlay. B. 5 cm of foam overlay.

time needed for a scan.

To date, CIBR has proven that it can resolve surface scans of complex images and that it has the possibility for significant image acquisition time gains over RSD. The remaining problems lie with subsurface scanning capability. The usefulness of x-ray technology is not primarily in surface scans, but in subsurface scans, at which RSD excels. By taking the same SXI lead-on-nylon target and placing it under varying depths of foam, CIBR was able to reconstruct the images in Figure 6, proving that it is also a viable subsurface interrogation technique.

Current research has demonstrated the proof-of-principle for the CIBR method. Tests have shown the ability to generate subsurface, high-complexity images using high-contrast objects at speeds greater than current RSD scanning capabilities. These images have been generated utilizing image reconstruction methods designed for CT systems, which do not directly correlate to the CIBR method of scanning. As CIBR-specific image reconstruction methods are developed and improved, image acquisition time is expected to continue to decrease. Continued research and development will continue to improve image quality, acquisition time, and overall quality of CIBR images. With the increase in speed, CIBR will become a more desirable choice for non-destructive testing.

MAJ Christopher Meng is a Course Director and Instructor at the United States Military Academy, in West Point, NY. He has a B.S. in Mechanical Engineering from the United States Military Academy, a M.S. in Engineering Management from the University of Missouri - Rolla, and a M.S. in Nuclear Engineering from the University of Florida. He was previously assigned as a student at the U.S. Army Student Detachment with duty at the University of Florida. His email address is christopher.meng@us.army.mil.

Collaborative Technology Advances Secure Global Communications

Mr. Jack Riegel
National Security Advisor, Office of Protective Services,
National Aeronautics and Space Administration (NASA)

Mr. Glen L. Scott
Chief Information Technology / VTC Facilitator,
U.S. Army Nuclear and CWMD Agency

USANCA is using a secure multi-point video conferencing solution allowing the Agency to conduct remote collaboration

Client

The United States Army Nuclear and Combating WMD Agency (USANCA) as a Headquarters, Department of Army, G3/5/7, Field Operating Agency provides the U.S. Army's core expertise in nuclear and related matters and advises and assists other Department of Defense, government and international organizations. USANCA is located at Fort Belvoir and is staffed with world-renowned military and civilian experts, principally scientists, physicists, and nuclear engineers.

Challenge

Translating the Agency Senior Leadership's vision as articulated by Dr. Martin Moakler, Chief of the CWMD Analysis Division was key in implementing an actionable solution. USANCA is small in size but it has far reaching impact with a large audience. In order to go about its business it needs to be able to set up, often at a moment's notice, secure communication channels to other military and government agencies worldwide. Jack Riegel, then Chief of Information Management at USANCA, said, "Voice communications alone is often not enough, face-to-face contact is very important."

This need to communicate regularly with various military and government activities around the world, and other security agencies means that USANCA team members spent a lot of time travelling. Implementing a responsive video conferencing solution served the dual purpose of reducing costs and decreasing coordination preparation time. Jack Riegel continues, "Our move into a newly renovated building at Fort Belvoir was planned to address our requirements for remote collaboration. A state-of-art enhanced secure video conferencing capability was high on the list of features envisioned by the Agencies' Senior Leadership." USANCA needed a supplier that could design and implement a state-of-the-art replicable solution that would cost effectively and meet U.S. security standards.

Solution

Cisco TANDBERG technology. The solution comprises multiple TANDBERG 6000 video conferencing units driving independent 65" displays suitable for up to 54 people in the main conference room; and other units driving six independent 65" displays in the separate multi-purpose conference room.

The video network was designed so that each video conferencing unit can independently support both unclassified and classified conversations. The system has IP-based connections for in house connectivity and ISDN connections for remote video conferencing; and the Cisco TANDBERG technology interoperates seamlessly with third-party terminals.

The encrypted network features the TANDBERG Media Processing System 800 developed specifically with security and compliance in mind for government departments. Two video communication servers, one for each network, control content distribution to all end-points, while an MCU 4500 conference bridge supports high-definition video distribution.
TANDBERG Management Suite provides complete visibility and control for all on-site and remote video systems.

This was a complex and time constrained project, from start to finish the majority of the implementation

took just 45 days. The contractors selected by G/3/5/7 continued to work proactively with us to iron out any issues necessary for us to operate and meet Department of Defense security benchmarks."

USANCA also has ongoing support to via a One Care maintenance agreement. This features a single point of contact, online fault reporting and tracking, help desk support around-the-clock, and next business day parts replacement – as well as the options of remote systems monitoring and quarterly performance reports.

Mr. Glen Scott, the Acting IM Division Chief, and system manager, stated "Dr. Moakler and Mr. Riegel have put in place an excellent VTC solution that will pay dividends for years to come."

Value

The new TANDBERG video conferencing solution is already delivering on its promise. USANCA has much improved communication and collaboration facilities and now able to hold multi-agency conferences on demand, bringing together people face-to-face without the need to travel. This is enabling enhanced information exchange and faster decision making.

Avoiding the need for air travel is also improving unit productivity as well as saving money. Early estimates suggest that annual travel cost savings could be significant.

The video conferencing technology has also opened up new opportunities. For example, it will be used for training sessions to extend the central knowledge base to remote and partner agency staff. Event recording capabilities will allow on-demand playback of training sessions for people unable to join the live event, overcoming boundaries of distance and time and helping to extend the reach and influence of USANCA still further.

The quality of project management, solution engineering, professional installation is very high, and USANCA is pleased with the outcome. The people we worked with had the right experience and the technical support has been second-to-none. Above all, the system has been extremely reliable. We have had no equipment failures, and right now everything is working perfectly."

G3/5/7 chose the partnership of BT Conferencing, EMW, Slye Electronics, and Zane Networks, for the extended project. The partnership gave USANCA real confidence that they understood the stringent security considerations for our working environment.

Mr. Jack F. Riegel, CISSP, CISA, CISM, is the National Security Advisor in the Office of Protective Services at the National Aeronautics and Space Administration (NASA) Headquarters in Washington, DC. He has a B.A. in Anthropology from Eastern Washington University. His previous civilian assignments include Chief, Information Management, USANCA, Information Assurance Program Manager (IAPM) NASA Special Programs, IAPM US Army Criminal Investigation Command (USACIDC).

Mr. Glen L. Scott is the Information Technology Manager/ VTC Facilitator at the U.S. Army Nuclear and Combating Weapons of Mass Destruction Agency (USANCA) in Fort Belvoir, Virginia. He was previously assigned as a Project Manager at the US Army Criminal Investigation Command (USACIDC).
His email address is glenn.scott@us.army.mil

A Brief History of the Defense Nuclear Weapons School

LTC Eugene V. Sheely
U.S. Air Force Institute of Technology

The Defense Nuclear Weapons School (DNWS) has a prestigious past that spans a 60 year period. During this time many organizational and name changes have occurred.

In 1947, the Armed Forces Special Weapons Project (AFSWP) was formed to provide military training in nuclear weapons' operations. The Nuclear Weapons Technical Training Group was organized as part of this Agency to provide resident and nonresident training in support of nuclear weapon training programs worldwide. The Group, created the Special Weapons School on the U.S. Army's Sandia Base, which is now part of Kirtland AFB.

In the 1950's, the name of the school (the Special Weapons School) was changed to the Atomic Weapons Training Group. By the end of the 1960's the training programs at the school had burgeoned with more than 90,000 graduates. In May of 1959 the school's parent organization, AFSWP changed its name to the Defense Atomic Support Agency (DASA).

In 1970 the school name was changed again, this time to the Nuclear Weapons School. The school was transferred to the U.S. Air Force in 1971 and the name was expanded to the Interservice Nuclear Weapons School.

During 1971 the Defense Atomic Support Agency (DASA) also had a name change. Its name was changed to the Defense Nuclear Agency (DNA). In 1993, the school was transferred back to its former parent organization, which was by this time called the Defense Nuclear Agency. In 1996 the name of the school's parent agency, DNA was again changed, this time to the Defense Special Weapons Agency.

In 1997 the school name was again changed, this time to the Defense Nuclear Weapons School (DNWS). In November of this same year, the Defense Reform Initiative directed that the Defense Threat Reduction Agency (DTRA) be created to strengthen and improve Weapons of Mass Destruction (WMD) threat reduction. DTRA, a designated combat support agency, was officially established on Oct. 1, 1998. This new organization absorbed the Defense Special Weapons Agency, the On-Site Inspection Security Administration, along with selected other elements of the Office of the Secretary of Defense staff. The Defense Nuclear Weapons School (DNWS) has been a part of DTRA since this time.

Throughout its history, the DNWS has supported the Office of the Secretary of Defense, the Joint Chiefs of Staff, the military services, and the combatant commands by providing training advice and services in the field of nuclear weapons. Training has been offered in weapons maintenance and emergency response. With the estab-

Defense Threat Reduction University.

From top: Defense Atomic Support Agency (DASA), Defense Nuclear Agency (DNA), Defense Special Weapons Agency
Center: Defense Threat Reduction Agency (DTRA)
Bottom: Armed Forces Special Weapons Project (AFSWP), and Defense Nuclear Weapons School (DNWS)
CW5 Gomes Collection

lishment of the DTRA in 1998, the DNWS expanded into WMD/CBRNE (chemical, biological, radiological, nuclear, and high explosive) response training, although, nuclear weapons instruction remains the core competency.

LTC Eugene Sheely is a former infantry officer, currently working as the combating weapons of mass destruction curriculum chair at the Air Force Institute of Technology. He has a B.S. in Chemistry from Brigham Young University, an M.S. in Physical Chemistry from the University of Idaho, and a Ph.D. in Theoretical Physical Chemistry, also from the University of Idaho. His major areas of research involve nuclear fusion and molecular dynamics. He previously served as the Academics Director of the Defense Nuclear Weapons School (DNWS), as a team leader on consequence management advisory teams and as the Chief of Environmental Health Physics and the Chief of Occupational Health Physics at the Air Force Institute for Operational Health.
His email address is: Eugene.Sheely@AFIT.edu.

One Second After

Mr. Robert A. Pfeffer
Physical Scientist
U.S. Army Nuclear and CWMD Agency

Too often technical writers concentrate on facts and fail to emphasize to their audience the importance of the topic. For example, those that write on high-altitude electromagnetic pulse (HEMP) effects on systems inevitably begin with a description of a nuclear detonation and how its detonation products interact with the upper atmosphere to produce the HEMP that eventually interacts with the ground and systems. While interesting to other scientists, HEMP phenomenology is not the important message to most: what is often on the minds of the readers is the short and long-term implications a HEMP event could have on the military and civilian population.

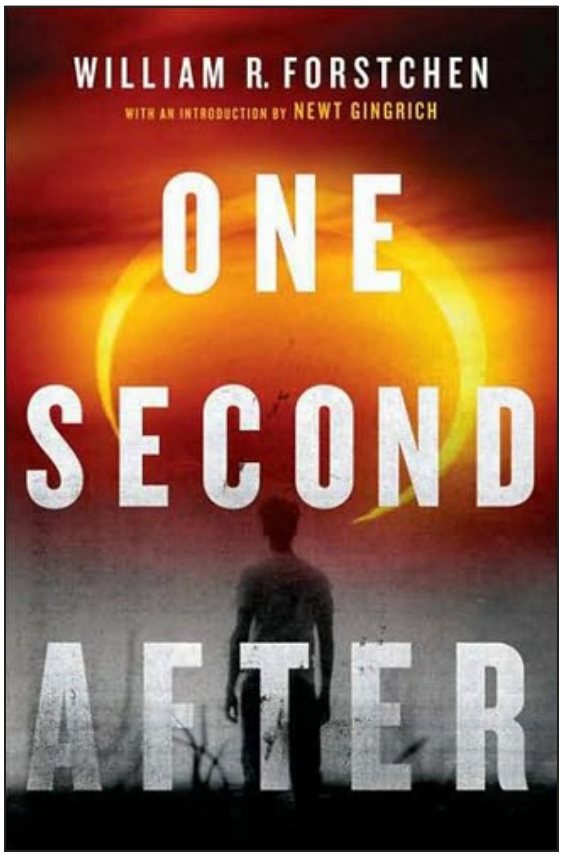
The novel "*One Second After"* by William R. Forstchen follows the life of a professor in a small North Carolina town just before and immediately after most all modern electronics fail in the East Coast. Immediate and long-term implications to civilian and military life become evident, creating massive long-term blackouts of the National Power Grid (NPG) and the catastrophic failure of individual electronic systems. Deaths, first to the very young, the sick and the very old, begin to create societal traumas that lead to first local and then regional violence that threatens the very society they live in.

The culprit that creates a HEMP environment is never identified, nor is the phenomena that creates HEMP, but the psychological and sociological implications of the event is portrayed in gory detail. While somewhat exaggerated, the story describes the implications of not being prepared for a low-probability, high-impact threat to the United States.

NOTE: Although HEMP is the threat for this story, one can substitute a severe solar storm as a similar electromagnetic (EM) threat to the NPG. Another EM threat that could be significant, but is also not covered in the novel, is cyber attack. For this reason, it is recommended that one read this novel to understand how the military and society in general could be affected once we no longer have electricity and electronics to maintain electrical power to process and refrigerate food and medicine, pump fuel, water, and sewage, maintain bank and stock market records and other databases, and provide light and air conditioning.

Editors note:
Please see the article in this issue titled, *"Electromagnetic Threats to the National Power Grid (NPG): An Update"* as a reference to this book to realize the scope of damage.

Source:
Forstchen, William R., *One Second After*, Forge Books, 352 pages, ISBN 978-0-7653-1758-2, March 2009.



Combating WMD Resource Page

Highlighted Courses available at the Defense Nuclear Weapons School (DNWS) and Defense Threat Reduction University (DTRU)

Theater Nuclear Operations Course (TNOC)

TNOC is the only course offered by a Department of Defense organization that provides training for planners, support staff, targeteers, and staff nuclear planners for joint operations and targeting. The course provides overview of nuclear weapon design, capabilities and effects to include U.S. nuclear policy, and joint nuclear doctrine. TNOC meets U.S. Army qualification requirements for the additional skill identifier 5H. The course number is DNWS-R013 (TNOC). Call DNWS at (505) 846-5666 or DSN 246 -5666 for quotas and registration information.

Next class availability:
21-25 Feb 2011
22-26 Aug 2011

Nuclear and Counterproliferation Officer Course (NCP52)

NCP52 is the Functional Area 52 qualifying course. Initial priority is given to officers TDY enroute to a FA52 assignment or currently serving in a FA52 position. There is limited availability outside of the FA52 community. Please call the FA52 Proponent Manager at (703) 806-7866 to inquire on available seats.

Next class availability:
11 Jul - 5 Aug 2011

Combating WMD Courses

The Defense Threat Reduction Agency hosts two Combating WMD courses, the Introduction to Combating WMD and Advanced Combating WMD.

The introductory course provides an overview of U.S. Government and Department of Defense strategy and policy relating to Combating WMD and instruction is focused around the three pillars of Combating WMD and the eight military mission areas.

The advanced course applies aspects of the Joint Operation Planning Process to Combating WMD related plans and operations. Both courses are taught using a combination of instructor-led modules and practical tabletop exercises.

For more information on course dates and registration information, visit the Defense Nuclear Weapons School's website at: https://dnws.abq.dtra.mil.
Mobile Training Teams are available upon request.

U.S. Nuclear Policy

This course covers U.S. Nuclear Policy and its history; reviews NATO policy; discusses nuclear deterrence: theory, principles, and implications; discusses instruments of national power and implications for nuclear weapons; reviews nuclear surety and intelligence; discusses nuclear treaties and arms control.

This course is taught at the Defense Nuclear Weapons School (DNWS)
Albuquerque, New Mexico

Email: dnws@abq.dtra.mil
Fax: (505) 846-9168 or DSN 246-9168
Online registration:
https://dnws.abq.dtra.mil/StudentArea/Login.asp

Next class availability:
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(703) 692-6855 DSN 222-6855

The Defense Nuclear Weapons School (DNWS) and it's parent organization has changed names over some 60 years. It is the only school dedicated to nuclear weapons operations. Since 1998, it expanded to WMD/CBRNE (chemical, biological, radiological, nuclear, and high explosive) response training.

From top to bottom: Defense Atomic Support Agency (DASA), Defense Nuclear Agency (DNA), Defense Special Weapons Agency (DSWA), Defense Threat Reduction Agency (DTRA)

Second row: Armed Forces Special Weapons Project (AFSWP), and Defense Nuclear Weapons School (DNWS)

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